Using Social Topography to Understand the Active Mobility Networks (AMNs) of People with Disabilities (PWDs)

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

This study explores the physical features in the urban setting that give rise to inequitable outcomes for people with disabilities (PWDs), in particular, those with mobility impairments. The objective is to identify the dynamic elements of local active mobility networks that act as barriers to PWDs. A review of the principles and metrics of contemporary urban and transportation planning theory and practice is undertaken. This is contrasted against studies that define the heterogeneous needs and preferences of the disabled population. From this, a new framework is introduced - social topography. This model visualizes the community as a network of opportunities embedded into the physical and socio-economic fabric of the community. It is used as a tool for assessing active mobility networks of three neighbourhoods centered on transportation hubs in southern British Columbia, Canada. The audits reveal that accessibility is a complex and dynamic concept that should inform urban and transportation planning policy and practice. The nuances of absolute and relative access challenges are revealed when the social topography framework is applied. In order to reduce the inequitable outcomes that exist, urban and transportation planning will need to reconsider the underlying principles implicitly and explicitly employed as well as the measures and tools deployed. In the end, individuals and communities will benefit from this more inclusive urban planning paradigm.

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1 INTRODUCTION

1.1 Problem

People with disabilities (PWDs) have fewer opportunities to fully participate in their own communities than the general population (Mulligan et al., 2012). Existing buildings, paths, and transportation systems present accessibility challenges that deter or outright exclude participation for some people. Programs and services that target able-bodied users further marginalize PWDs. Combined, they result in an inequitable society where social, economic, and health outcomes are consistently worse for PWDs than they are for the able-bodied population (Brown & Emery, 2010; Clarke et al., 2008; Crooks, 2007; Edwards, 2001; Kitchin, 1998).

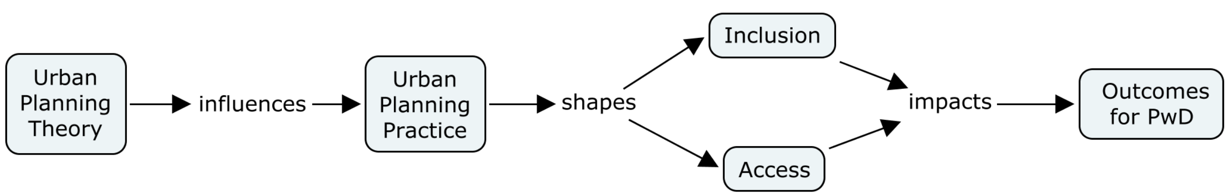


Figure 1.1 Planning influence on outcomes for PWDs.

Figure 1.1 represents the process with which opportunities for participation by PWDs are mediated by planning theory and practice. The sources of these outcomes are direct and indirect. Directly, contemporary urban and transportation planning practices contribute to opportunities by shaping **access** to the physical infrastructure and **inclusion** to programs and services. A key component to the physical infrastructure is the mobility network – the modes of travel people choose to navigate their communities. The predominant choice today is the automobile but ‘active mobility’ alternatives that don’t rely on motorized vehicles are critical to a sustainable future. In order to encourage walking, cycling, wheeling, and even transit use, a more walkable infrastructure is needed. However, policies and practices adopted by communities are not meeting the needs of PWDs. Pathways that are too narrow, surfaces not maintained, and non-existent accessibility maps are just some examples of this failure. Some of this gap can be attributed to the fact that architects, landscape architects, transportation planners, and urban planners rely on limited resources and training for guiding their efforts. As Lewis (2009) notes, awareness training for students in these fields can be the first step in changing attitudes. High-level policy statements, narrow compliance standards found in building codes, and generic urban design principles are not enough to meet the challenge. In addition, communication across city departments (e.g., between urban planning, transportation planning, and engineering) tends to be fractured (Berg, 2009; GVRD, 2013; Woudsma, 2007), resulting in disconnected plans, implementation, and monitoring.

Indirectly, practitioners adopt popular urban planning models like New Urbanism, Smart Growth, Transit Oriented Development (TOD), and Transportation Demand Management (TDM) without considering the implications to PWDs. These models place considerable emphasis on generic objectives like density, design, and diversity (Cervero & Kockelman, 1997). They explicitly and implicitly adopt principles and measures that are modeled on the 'typical' or 'average' adult citizen (Imrie, 1996; Kitchin, 1998; Matthews & Vujakovich, 1995). But, what is typical or average? Is this the same at all times and places? Is it even a desirable target? Without a greater understanding of the needs and preferences of PWDs, it is not known if these are, in fact, false proxies for PWDs. A promising change in transportation planning is a shift in emphasis from the *mobility* efficient road networks can produce to the *accessibility* effective transportation choices offer (Lin et al., 2012; Rubulotta et al., 2013).

However, integration of the needs of PWDs has been slow in this area of research as well (Duvarci & Yigitcanlar, 2007; Martens, 2012).

What we do know is that urban and transportation planning continues to underserve PWDs, and the communities they live in (Bromley et al, 2007; Gleeson, 2001; Greed, 2011; Hagg, 2008; Imrie, 2000; Imrie, 2013; Imrie & Kunmar; 1998; Mojtahedi et al., 2008; Pineda, 2008; WHO, 2013). As an extreme example, a judge ruled that the city of New York failed to adequately plan for 900,000 people with disabilities prior to Hurricane Sandy's devastation (Clifford, 2013). Whether it is acute emergency failures or chronic health inequities, planners need to rethink the assumptions behind existing models and practices - and the impact their decisions have on all citizens (Kirchner et al., 2008).

The fact that urban and transportation planning can play an important role in improving the quality of life for PWDs is cause for optimism. A great deal of research has shown that planning practices influence people's ability to be active in their communities (Boarnet et al., 2008; Frank et al., 2007; Saelens & Handy, 2008; Sallis et al., 2004). In particular, active mobility networks – AMNs (i.e. non-motorized travel options used for completing daily tasks as well as recreation and exercise) play a significant role in realizing positive outcomes like better citizen health, access to employment, and greater engagement in the community. In an extensive review of the literature, Thomas and Barnes (2004) identified lack of mobility as the most critical factor for life expectancy. In other words, AMNs are important and more must be done to better understand them to make them accessible to everyone.

However, there is a large gap in the literature with respect to the benefits of active mobility for PWDs (Asadi-Shekari et al., 2013; Church & Marston, 2003; Handy & Niemeier, 1997; Lewis, 2009; Prince, 2004, 2008; Spivock et al., 2007) or how to measure it (Seekins et al, 2013). According to the World Health Organization's (WHO) World Report on Disability (2011), PWDs have a harder time being healthy because of a lack of accessibility in their community and the resources to take advantage of existing opportunities. In an economic climate that stresses maximizing returns on investment, urban planning decisions need to be strategic in the utilization of infrastructure and delivery of services. Accessible and inclusive design practices are key pieces to the puzzle. Before planners can design and implement solutions that serve the public more efficiently and effectively, they must understand the contextual foundation of this challenge.

1.2 Research Objectives and Questions

This research will focus on building a greater understanding about how planners can address the needs and preferences of PWDs to utilize active mobility networks (AMNs). In particular, focus will be on how those with mobility impairments (i.e. people who use manual and motorized wheelchairs) access opportunities like visiting neighbours, going to school and work, shopping in local stores, and exercising in their own neighbourhoods, by way of sidewalks, paths, and trails (i.e. active mobility networks). Two facets of environmental constraints will be considered. The first constraint is an absolute physical barrier like a set of stairs or a steep slope that stops a person from continuing forward. The second type is a relative physical barrier that is a result of conditions that, on their own, would not impede progress but, in combination, limit access (e.g. a surface with a 5% slope, 2% cross-slope, and 920mm wide will reduce the distance someone in a manual chair might travel). This research will examine how current approaches that only consider absolute barriers (if barriers are considered at all) are insufficient for understanding how to promote inclusive and walkable environments. In order to address these challenges, this research asks these key questions:

1. What physical barriers – absolute and relative - exist for PWDs for getting around their own communities?
    a. How are the needs and preferences of PWDs contrasted against the environmental constraints active mobility networks (AMNs)?

2. What does the active mobility network (AMN) look like from the perspective of a person with a disability?
    a. How well connected are people to daily activities (e.g., work, play, learn, socialize, shop, etc.) by the network of sidewalks, paths and trails (i.e. accessibility)?
    b. How do these active mobility networks compare across disability types and to those of the able-bodied population (i.e. equity)?

3. How have models from urban and transportation planning as well as those from disability studies impacted the design and development of accessible mobility network (AMNs)?
    a. What planning principles and measures help to shape active mobility networks?
    b. What policies, practices, and tools influence accessibility?

1.3 Purpose

The purpose of this study is to understand and quantify the accessibility of active mobility networks (AMNs) for PWDs and to assist urban and transportation planners design, develop, and manage AMNs that meet the needs and preferences of PWDs. The main goal is to develop a methodological approach, if none currently exists, that incorporates the heterogeneous needs and preferences of people with mobility impairments against environmental constraints present in typical AMNs. In order to do this, the study will examine existing planning theories, practices, and tools to identify gaps. The focus is on urban and transportation planning responses that have more direct impact on urban form than higher-level disability related policies. A case study of 3 transit-oriented neighbourhoods will be used to describe and quantify accessibility challenges using the proposed approach. Future studies involving a broader array of impairments and mobility devices will help to address other needs (e.g. visual impairments or people who use walkers) and make such a model more robust.

1.4 Thesis Organization

This study will begin by explaining what active mobility networks are, what their benefits are and how they come about through planning theory and practice. An historical perspective of key planning models will be reviewed to provide a contextual background of the motivators for their adoption and the strategies required to make planning more inclusive in the future. This is contrasted against the inequitable outcomes experienced by PWDs. Based on advances in disability models and studies of the needs and preferences of PWDs, an approach that embodies the daily lives of PWDs can be established. This model is then leveraged in a case study of 3 transit hubs in dense urban neighbourhoods. The analysis from these case studies will bring to light the nuanced nature of accessibility and the challenges that planners must address if AMNs are to meet the needs of all citizens.

Chapter 1 is an introduction to the thesis. It begins with a statement of the problems and the research questions being asked to address these problems. This is followed in Chapter 2 by a literature review. It is divided into sections that 1) introduce AMNs and their principles, measures, and benefits, 2) examine the role urban and transportation planning theory has in contributing to the current state of AMNs, 3) highlight the inequities that exist between PWDs and the general population leading to the rationale for rethinking existing approaches, and 4) examine the needs and preferences of PWDs in light of the environmental constraints on mobility. This allows for the consideration of an alternative model to inform the case study development and analysis.

1.5 Key Concepts

The key concepts in this research are:

- ***Active transportation*** **(AT)** refers to non-motorized modes of travel for utilitarian purposes (e.g. traveling to work, grocery store, restaurant)
- ***Active recreation*** **(AR)** refers to non-motorized modes of travel for leisure, recreation, and exercise purposes (e.g. cycling, jogging, walking)
- ***Active Mobility Networks*** **(AMNs)** are the active transportation and recreation options that connect people to opportunities in their communities and can be visualized as a network of nodes (features) and links (sidewalks, paths, and trails) in a community (Sallis et al., 2004).
    - ***Opportunities*** exist in the community to live, work, play, learn, socialize etc.
- ***Walkability*** is the qualities of a neighbourhood that encourage active travel and recreation
- ***Accessibility*** is the ability of an individual to successfully traverse the natural and built environment
    - ***Absolute Accessibility*** is an attribute in the environment that acts as a barrier to full participation (i.e., a barrier).

Relative Accessibility is the accumulation of factors in the environment that act as a barrier to full participation (i.e. a combination of attributes that, on their own would not be a barrier but, when added up, constitute a barrier).

- ***Inclusion*** is the degree to which everyone can participate in an activity.
- An ***Ability Profile*** (AP) describes the accessibility needs and preferences of an individual
- ***Environmental Constraints*** **(EC)** are the attributes in the environment that challenge access
- ***Social topography*** is the network of linked opportunities embedded into the physical and socio-economic fabric of the community
- ***Mobility*** in the transportation planning literature refers to the efficiency of transportation systems to facilitate convenient travel (usually automobile focused)

2 LITERATURE REVIEW

2.1 Introduction

The literature review is divided into three parts (Figure 2.1). The first part introduces active mobility networks (AMNs) and the principles and benefits of walkability. AMNs are the non-motorized mobility options people have for moving about their neighbourhoods and cities. They are made up of overlapping infrastructures for active transportation serving utilitarian purposes and active recreation serving leisure, recreation, and exercise purposes. Both of these networks are connected to transit and motorized transportation modes. AMNs have been linked to significant benefits for individuals and communities and are a product of urban and transportation planning theories and decisions. The first part of the literature review will examine, in greater detail, the links between urban form, walkability, urban and transportation planning theory, and planning policies and practices in order to build a picture of the current state of AMN approaches.

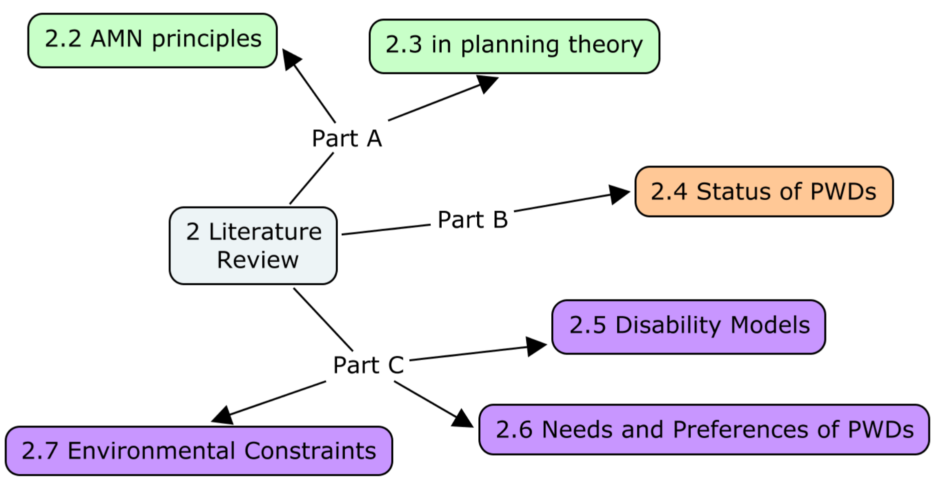


Figure 2.1 Literature review map.

The second part of the literature review demonstrates that the underlying principles and practices identified in the first part are not meeting the needs of PWDs. Evidence of significant inequities existing between people with and without disabilities from social, economic, and health perspectives fortifies this claim. The reality of ageing demographics and the growing numbers of PWDs that accompany this trend emphasize the rationale for undertaking this study.

The third part of the literature review synthesizes the needs and preferences of PWDs in order to understand and evaluate AMNs from the perspective of those with varying ability levels. Accessibility and inclusion are defined and examined within an historical context that considers how disability models have shaped the conversation. This will help build ability profiles (AP) defined by the needs and preferences of PWDs in light of the environmental constraints that exist. Urban planning, transportation planning, and public health research provide the backbone of the literature review.

2.2 Active Mobility Overview

The literature review explores the thesis that active mobility networks are a benefit to the community and that urban planning theories and practices help to shape them. The purpose of this section is to explore active transportation and active recreation – collectively, active mobility networks (AMNs) - in relation to urban form (i.e., the pattern a city exhibits as a consequence of its land uses and transportation systems) as expressed through the mobility behaviours of individuals (i.e. walkability). The review begins with putting active transportation and active recreation into context and providing a brief history of how AMNs have emerged in their theoretical and practical settings. This review will explore the principles and measures that establish baselines for operationalizing AMNs and walkability. As a consequence, a comparison between this baseline and the needs and preferences of PWDs can be conducted.

A number of disciplines have tried to better understand the dynamic interaction between individual choice and environmental conditions. Public health studies and urban planning have taken divergent paths to address this dynamic until more recently (Sloane, 2006). Historically, the health field has focused on individual factors that influence physical activity while urban planning literature examined elements of urban form that appear to impact travel behaviour (Hoehner et al., 2003). Their independent findings are now starting to converge into more comprehensive models. More recently, collaboration between the disciplines has led to programs like Active Living by Design, Complete Streets, Healthy Communities, active transportation, and active recreation. Large foundations like the Robert Wood Johnson Foundation have dedicated a great deal of funding ($28 million since 2000) towards the active living agenda in the U.S. (Robert Wood Johnson Foundation, 2008) as an example. In Canada, provinces like Manitoba have set up a Small Communities Active Transportation Fund to support the development of active transportation infrastructure (Government of Manitoba, 2013). These, and many more initiatives, are indicative of the momentum AMNs are experiencing.

In order to understand the dynamics of AMNs, a social ecological approach is leveraged in this study. The social ecological perspective speaks to the link between the environment and mobility behaviours as demonstrated in the literature. The following sections will further explain the social ecological model, components of AMNs, mobility decision factors and composite measures (i.e. walkability indices), the potential benefits of AMNs, and the limitations of the studies reviewed. In the end, it is these limitations that hint to a need for re-examining the applicability of the models proposed and the generalizability of their findings towards the disabled population.

2.2.1 Mobility Networks

Active transportation and active recreation are part of the broader transportation options people have for accomplishing their daily activities as shown in Figure 2.2. Motorized options, dominated by the automobile, have been the focus of planners since their proliferation in the 1950s. In this paper, active transportation is defined as the non-motorized mobility options that serve utilitarian purposes (e.g. walking to the bank, cycling to work, or wheeling to the market). Underlying walking, cycling, and transit infrastructure like sidewalks, paths, bus stops, maintenance practices, wayfinding, policies, etc., shape the state of a community's active transportation network. Active recreation leverages much of the same infrastructure but its purpose is to support leisure, recreation, and exercise and is more likely to include park paths and trails (Cerin et al., 2006; Hoehner et al, 2005; Kerr et al., 2005; Saelens & Handy, 2008). Together, the active transportation and recreation infrastructure will be collectively referred to as the **active mobility network (AMN)**.

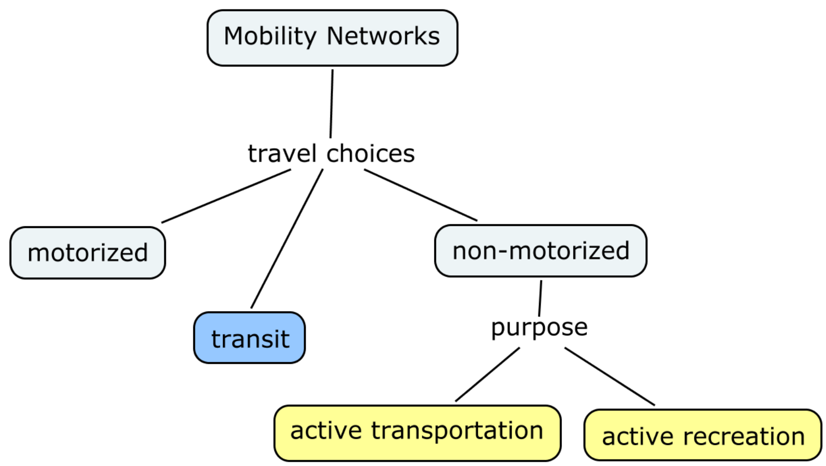


Figure 2.2 Mobility networks.

AMN infrastructure that promotes physical activity is defined as walkable. Walkability is the ability of citizens to access community resources located through the existing AMN infrastructure (i.e., the urban network). Brownson et al. (2009) boil walkability down to the "…proximity and directness of routes from home to destinations" (p. S99). Simply building a walkable infrastructure does not ensure people will make active mobility choices but does provide the physical foundation to make active mobility possible (Badland et al., 2009; Saelens et al., 2003).

The ultimate goal for achieving greater utilization of the AMN infrastructure and getting people physically active is more complex than that. 'Build it and they will come' is not enough. AMNs are supported by a diverse set of stakeholders with varying roles and responsibilities for activating these networks. On public lands, multiple levels of government share the responsibility for ensuring that the system meets everybody's needs and runs efficiently and effectively. Businesses and not-for profit agencies provide value-added opportunities that address physical and service experiences. Alignment between these stakeholders is required to efficiently and effectively develop sustainable AMNs (Aboelata et al., 2011).

Most research makes a connection between urban form and walkable environments (in addition to other policies and practices). The differences lie in the nature and intensity. More definitively, the benefits of promoting AMNs are well supported in the literature. Boarnet et al. (2008), Frank et al. (2004), Frank et al., (2005), and Litman (2003) all point to health benefits like reductions in obesity, environmental pollutants, and even traffic accidents as consequences of walkable AMNs. Rabl and Nazelle (2012) specifically identify a reduction in exposure to ambient pollutants as a significant benefit in active transportation versus automobile use that benefits driver and pedestrian.

2.2.2 Social Ecological Model

In order to examine the role AMNs have in addressing the fundamental issues posed in this study, a social ecological model is used. The social ecological model stresses the interplay between individual, social, and environmental influences on behaviour (King et al., 2002; Lee & Moudon, 2004). Sallis et al. (2006) illustrate (see Figure 2.3) how intrapersonal, interpersonal, organizational, community and public policy systems factors can influence individual behaviours in four domains of active living:

1. Activities around the home
2. Activities around work
3. Activities for utilitarian purposes
4. Activities for recreational purposes

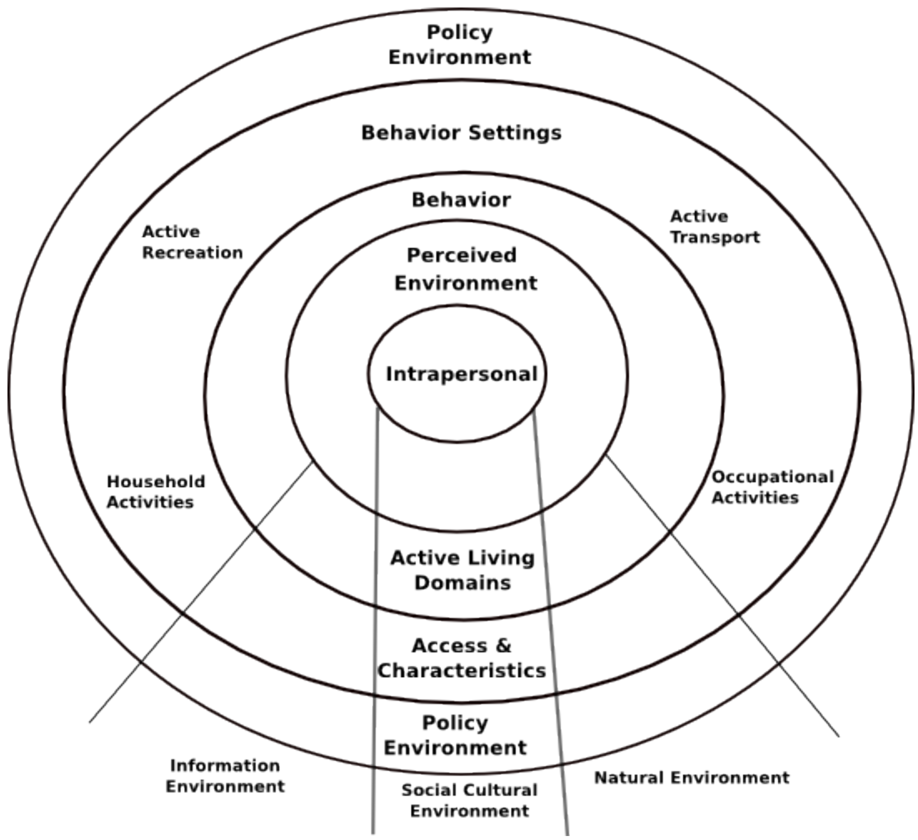


Figure 2.3 Social ecological model. (Adapted from: Sallis, et al., 2006, 301).

Therefore, policy decisions (e.g. transportation policies, zoning bylaws, housing strategies) need to address the social, cultural, political, and physical environments. According to Sallis et al. (2006), promoting safe, inviting environments through diverse media channels will encourage increased use of active transportation options. McCray and Brais (2007) introduce time as another variable to factor into policy and design. For example, how people interact with their environment is influenced by personal schedules and the real and perceived safety differences at varying times of the day.

While the focus of the social ecological approach is primarily on health behaviours, it lends itself well to examining AMNs and the link to purported economic and social benefits. Hoehner et al. (2003) emphasize the benefits of converging the public health focus on recreation, leisure and exercise with urban planning's focus on utilitarian transportation towards broadening and deepening an understanding of active mobility in the research. For example, the evolution of the active living perspective offers a more integrated model for policy decisions than approaches that only try to change individual behaviour.

Early findings from this approach are promising but not definitive in terms of a causal link between urban form and physical activity. For instance, reliance on cross-sectional research precludes making direct cause and effect conclusions (Brownson et al., 2008; Saelens & Handy, 2008).

2.2.3 Active Mobility Networks (AMNs)

A key aspect of people's lives is the non-motorized travel that takes place between where they live and where they work, learn, play, socialize, etc. Effective AMNs have demonstrated significant social, economic, and environmental benefits for individuals, communities, and beyond in both research and practice. However, as Glaeser depicts in Triumph of the City (2011) and echoed in Lorinc's The New City (2006), cities have been built for the auto, not human powered transport. In neighbourhoods where people have multiple options for travel, the automobile still predominates.

The question researchers are asking and planners are trying to address is - what factors influence transportation mode choice? Walking, cycling, transit, and some combination of the three are alternatives to the single occupancy motorized trips that seem to prevail (Cervero & Kockelman, 1997; Frank & Pivo, 1995). In order to understand this, factors influencing travel behaviour have been identified and measured for impact. This research is maturing and a movement to create aggregate measures of walkability to combine and simplify the relationship between factors has emerged (Christian et al., 2011; Doyle et al., 2006; Giles-Corti et al., 2006; Leslie et al., 2007; Manaugh & El-Geneidy, 2011).

Sallis et al. (2004) conducted an extensive review of active living from the planning, health, and transportation perspectives. They drew connections between urban form, transportation choices, and health outcomes. A combination of urban design, land use patterns, and transportation systems that promote walking and cycling help create active, healthier, and more livable communities (Handy et al., 2002). In fact, the physical and social environment in which an individual lives may have a substantial influence on his or her physical and mental health (Beard et al., 2009). The next section will look deeper into these principles and measures.

2.2.4 Principles and Measures of Urban Form on Mobility Decisions

Many studies show a significant relationship between the built environment and physical activity (Cervero, 2002; Ewing et al., 2003; Frank et al., 2010c; Saelens & Handy, 2008). Factors like density, diversity, and design (i.e., the 3Ds), in particular, are leading factors in the research agenda. While the influence of urban morphologies appears to be significant, the nature of the relationship between urban form variables and travel behaviours has proven to be somewhat unclear. Before a definitive causal relationship can be established, Bauman et al. (2002) believe a distinction between determinants and correlates needs to be addressed more fully. They feel that without considering mediating, moderating, and confounding factors in research design, it is difficult to accurately describe the strength and direction of factors that influence mobility decisions. One distinction researchers have found in this regard is that there are significant differences between AMNs based on the purpose of the trip - utilitarian versus leisure-recreation purposes (Owen et al., 2004). In a summary by Sallis et al. (2006), only mixed land use and pedestrian infrastructure consistently display positive influences on physical activity for active transportation and active recreation.

Frank et al. (2005) point to three aspects of urban form that influence physical activity: land-use mix, residential density, and street connectivity. Their research fills a large gap in assessing activity at the individual as opposed to aggregate level. The researchers acknowledge that the self-selection bias of where people choose to live may also play a role (as a confounding factor) that may diminish the significance of the results.

The increase in AMN research can be attributed to growing health issues like obesity, diabetes, and other physical activity related diseases as well as concerns about pollution from automobile dependence. The three key environmental correlates of travel mode choice most often identified in research are density, diversity, and design (Alves & Ramalho, 2011; Cervero & Kockelman, 1997; Leslie et al., 2005). However, according to Agrawal et al. (2008), design has received limited attention in many of these studies as it is often the most difficult to measure. Other correlates include distance, safety, security, aesthetics, time, and more. The following sections will review the correlates and define the measures used to explain them. In many cases, correlates exhibit overlap (mediating factors) in their influence (e.g. when a neighbourhood is dense, it is likely that destinations are close by).

a) Density

Hodge and Gordon (2013) review the historical response to changing urban environments as rooted in cities that were dense, overcrowded, riddled with crime and poverty, and teeming with noxious hazards. Parks, sanitation, and improved sewerage were the initial response to these issues. By the middle of the 20th century, urban renewal led to razing of entire blocks, removing the inner city of 'unsightly blight' and allowing for highways to connect to the new suburbs. Where resistance to these trends failed, people were displaced and inner cities became hostile to pedestrians and cyclists (Hodge & Gordon, 2013).

In the 1960s, advocates like Jane Jacobs (1961) and Paul Davidoff (1965) brought into question urban planning practices that put unbridled efficiency ahead of social equity and environmental sustainability. Since then, the ever-growing suburbs sprouting on the edge of cities have cultivated sprawl externalities (Ewing et al., 2003). Residential land use zones with large single-family homes, large manicured lawns, and room in the garage for two cars have driven back city limits, distancing people from the city centre.

After an oil crisis in the early 1970s, the rise of environmentalism, and growing concerns about the health of people, urban planners were presented with a daunting challenge (Heinberg, 2011). In response, density has become a panacea for sprawl in the literature and on the ground (Gordon & Richardson, 1997; Gonzalez & Grant, 2011). A dense neighbourhood means resources are close by and economies of scale for public infrastructure can be achieved. A more measured approach that balances economic, social, and environmental externalities have emerged in places like Portland, Seattle, and Vancouver (Hodge & Gordon, 2013).

From a technical perspective, density can be measured as population density, dwelling and residential density (Bento et al., 2003), jobs-housing balance, and employment and shopping density (Frank et al., 2010b). Population density is the number of people found in a developed area whereas residential density is the number of residential units within a residentially zoned area (Cervero & Kockelman, 1997). The data for calculating these densities can usually be found in the census and municipal geographic information systems (GIS). Density can also be described using proxy measures. Neighbourhood age, for instance, is associated with more traditional neighbourhood designs that tend to exhibit higher residential densities (Badland & Schofield, 2005). Brownson et al. (2009) have used proximity and route directness as measures of density that influenced travel choice.

Density is highly correlated with physical activity in many studies (Atkinson et al., 2005; Badland & Schofield, 2005; Badland et al., 2009l Cervero, 2002; Frank & Engelke, 2001). Cervero and Kockelman (1997) found density to be the most correlated factor of travel choice, accounting for 47.6% of the environmental impact on physical activity. The dense grid pattern layouts found in traditional neighbourhoods predicted higher physical activity levels than in less dense neighbourhoods (Badland & Schofield, 2005; Bento et al., 2003; Cevero & Kockelman, 1997). The Heart and Stroke Foundation of Canada (2005) reported that people in dense neighbourhoods were 2.4 times more likely to meet physical activity guidelines than those in less dense communities, emphasizing the myth that it is healthier to live in the country or suburbs. In fact, Atkinson et al. (2005) demonstrated that density and vigorous recreational activity were positively correlated. Similar findings linking elements of urban form to physical activity were found in Canada by Craig et al. (2002).

b) Diversity

In response to the environmental and health challenges at the start of the 20th century, planners and public health professionals sought to separate conflicting land uses. The emergence of single-purpose zoning was intended to create safer and healthier neighbourhoods by creating a distance between the noises, smells, and byproducts of industry from residential neighbourhoods (Hodge & Gordon, 2013). However, the unintended consequences have been to move people further and further away from employment and retail opportunities. As transportation technologies (e.g., street car, subways, automobile) have evolved and become more affordable, distance has become less of a concern. Today, for example, 46% of Vancouver, Canada residents spend 30 minutes or more commuting to work (Turcotte, 2011). Turcotte (2011) also found that, across Canada, transit users take 44 minutes to get to work as opposed to 27 minutes by car and 14 minutes walking or cycling. In order to address this challenge, opportunities for employment, shopping, visiting the doctor, etc. need to be within walking distance (Cerin et al., 2007).

Density, on its own, does not make a city walkable - there has to be something to walk to for it to be worthwhile – “destinations that matter” (Cerin et al., 2007). Diversity at the destination is an attractor that makes density more effective. However, diversity is not a simple factor to measure. A common approach is to use a spatial calculation known as entropy. Simply put, it assesses how varied the land use is within a given area. It can also be measured as the balance between jobs and housing in a defined land area (Ewing & Cervero, 2010). Frank et al. (2010a) define diversity through land use mix by comparing the ratios of five land use types within a defined area: residential, retail, entertainment, office, and institutional uses. If there is an even split among the five types, that area gets a perfect score of 1 (score are normalized between 0 and 1). A score of 0 indicates only 1 land use in that area. Other studies use land use types in their entropy scores (Christian et al., 2011) or perceived land use mix to support their research (Leslie et al., 2005).

Mixed land use is correlated with greater physical activity (Badland et al., 2009; Brownson et al., 2009; Cervero & Kockelman, 1997; Cervero, 2002; Evans, 2009; Frank et al., 2005; Saelens et al., 2003), lower incidence of obesity (Frank et al., 2004), and less auto dependence (Chatman, 2009). Craig et al. (2002) found similar relationships between land use and physical activity rates in Canada. It is also important to consider that diversity factors interact with density and distance (moderating factors). When grocery stores and other retail offerings are within 300m, physical activity levels rise (Cervero, 1996). For non-utilitarian travel purposes, factors like aesthetics are more likely to impact travel mode choice (Beenackers et al., 2011) but evidence is still inconclusive on this point (Cao et al., 2007).

c) Design

The most difficult of the 3Ds to define is the design element because of its subjective nature. Despite the fact that urban design is believed to offer the greatest potential impact on influencing physical activity, researchers and practitioners feel that it is the most costly and least likely to be acted upon (Brownson et al., 2008). Measures of design used in the literature include such as:

- Land use mix
- Intersection density and proportion of four-way intersections
- Distance and block length
- Street pattern and connectivity
- Cycling/pedestrian infrastructure
- Safety from crime
- Sidewalk conditions (including lighting, amenities, traffic speed/calming, aesthetics, and presence of trees)

These measures are utilized in many studies (Atkinson et al., 2005; Badland et al., 2009; Bussel et al., 2009; Cervero & Kockelman, 1997; Cao et al., 2007; Christian et al., 2011; Frank & Engelke, 2001; Frank et al., 2005; Giles-Corti et al., 2005; Hess et al., 1999; Pikora et al., 2003; Saelens & Handy, 2008). In addition, factors like even and wide sidewalks, traffic control devices at crosswalks, and buffers to heavy traffic are identified as improvements to walkability (Agrawal et al., 2008). Beenackers et al. (2011) identified safety as a dimension important to walkability. Other studies found little or no correlation between design factors and recreational walking (Atkinson et al., 2005; Lee & Lee, 1998). Aesthetics, like public art, trees and plants influence travel choice for recreation and leisure purposes primarily (Agrawal et al., 2008). Alves & Ramalho (2011) also point to sidewalk continuity and comfort as enhancing the public space experience, contributing to design that promotes physical activity.

d) Distance

In addition to the 3Ds, (Lee & Moudon, 2006) add distance as another factor. The way distance is measured can make a difference in the results made. Distance can be measured in three ways:

1. Straight-line distance (as the crow flies) from the origin to a destination
2. Distance following the street network between origin and destination
3. Distance following the pedestrian network (including short-cut paths, park trails and other options that might not show up on most formal maps)

Research relying on straight-line distance trades in accuracy of actual travel distances for the ease and reduced effort of collecting data. For example, someone who needs to get to the middle of an adjacent street has their travel distance significantly reduced by a mid-point path between residences. Sometimes distance is reflected in other ways that take into considerations the nature of the path conditions. One approach is to substitute time or effort in place of distance (although this is a much more subjective value). Distance is a factor and has been shown to influence obesity (Frank et al., 2004).

Most studies have found that distance is one of the biggest factors impacting travel mode choice (Arentze et al., 1994). Historically, 400m straight-line circular buffers (about 5 minutes walking at 4.8km/h) around a specified point constitute the distance people are willing to travel one way although this may vary for some transit options (Guerra et al., 2012). One study found that people are willing to travel up to 800m to get to a rail station but still put a premium on shorter distances (Agrawal et al., 2008). It appears transit, as a destination, has different dynamics than shops and amenities based on factors like frequency of service.

Another aspect of distance overlooked is in measuring how a trip actually takes place. Depending on the purpose, a trip may be a simple there and back or it may include any number of stops in between. This idea of trip chaining is overlooked by many studies and may modify distances people are willing to travel (Arentze et al, 1994). Perceived distance is yet another variable that impacts mobility decisions (Cerin et al., 2007).

2.3 AMNs in Planning Models

This section examines how urban and transportation planning models have integrated active mobility into their principles and measures. I will discuss the contemporary models like New Urbanism, Smart Growth, Transit-Oriented Development (TOD), and Transportation Demand Management (TDM). In particular, the literature review will concentrate on the core elements of mobility design factors adopted by these models. In conclusion, common attributes are drawn out to use in the discussion about active transportation.

The planning reform models discussed below have a common historical driver – urban sprawl. Sprawl is defined as the outward spreading of low-density (usually residential) uses occupying large lots and inefficiently tapping into community infrastructure (Daniels, 2001; Downs, 2005). As cities grow outwards, distances between home and work grow, dependence on the automobile increases, and health and environmental conditions are exacerbated (Ewing et L., 2003; Filion & Kramer, 2012). The responses examined below have addressed active mobility in similar ways.

2.3.1 New Urbanism

According to the Charter of New Urbanism (Congress for New Urbanism, 2001), the intent of New Urbanism is to revitalize cities by rejuvenating the core and halting the effects of sprawl. Its principles are focused on economic, cultural, and environmental action at the metropolitan, neighborhood, and block level. The Charter declared that compact, pedestrian friendly, and mixed-use neighborhoods are essential to achieve its objectives. These efforts must be supported by a regional transportation strategy that alleviates the demand for using the auto for daily activities (i.e., auto dependency).

A study by Rodriguez et al. (2006) found that residents in neighbourhoods that exhibited the principles of New Urbanism walked and cycled much more and drove less than those in less dense environs, especially for utilitarian purposes. One reason for this may be the principle of permeability (i.e. fewer barriers between origin and destination) that grid street network patterns provide. This urban morphology allows for more direct paths between origin and destination (Cozens & Hillier, 2008). These authors also point out neighbourhoods with curvilinear street patterns and cul-de-sacs can achieve similar results with paths and trails between streets (i.e., fused grid morphology).

New Urbanism recently included the principle of visitability as part of its Charter. Visitability refers to homes with no steps upon entry, wider hallways, and larger bathrooms with accessibility features. The idea is that a home should be easy for anyone to enter (Maisel, 2006). However, beyond a few measurements for the home, not much attention is paid to accessibility in the New Urbanism model.

2.3.2 Smart Growth

Smart growth has been a widely used approach to manage urban growth and development through private-public partnerships (Daniels, 2001). According to Gordon (2003), New Urbanism is an attempt to shape travel behaviours through urban form and less about actual design.

According to Smart Growth Online (n.d.), Smart Growth has ten key principles:

- Mix land uses
- Compact building design
- Variety of housing options (including affordable housing)
- Pedestrian-friendly infrastructures to promote walkability
- Develop a sense of place and community
- Environmental preservation, including open space in cities
- Bolster existing development first (revitalize inner cities, infill)
- Provide travel route options
- Ensure predictable policies and practices
- Engage stakeholders

Downs (2005) identifies measures like increasing residential densities, providing mixed-use land opportunities, charging consumers for externality costs, improving transit, and revitalizing decaying areas to meet the objectives above. Transforming the built form and other infrastructure elements like creating street grids, narrowing streets, making the pedestrian environment safe, and providing frequent crosswalks directly impact AMNs.

2.3.3 Transit-Oriented Development (TOD)

In a comprehensive literature review of transit-oriented development (TOD), Cervero, et al. (2002) summarizes the state of TOD research at the time. TOD stresses building up commercial uses around transit hubs, mixing land use, providing comfortable amenities, and designing for pedestrians and cyclists. TOD is intended to be about people and solutions should come about through collaboration with all stakeholders. In other words, the process of getting to a design is as important as the design itself.

Because TOD focuses on transit, the scope of stakeholders impacted will widen to include regional interests. Crafting a strategy for designing solutions becomes inherently more complex. Handy (2005) outlines how transportation decisions guide land use decisions, which impact travel patterns (see Figure 2.4). This relationship needs to consider everyone that will be traversing the land in order to get the highest return on investment.

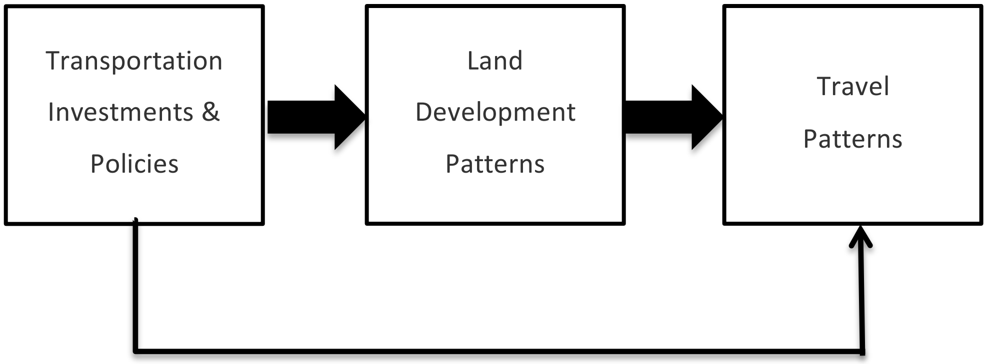


Figure 2.4 Influence of urban form on travel behaviour. (Source: Handy, 2005)

Interestingly, one study found that the walkability of transit destinations actually had a greater impact on ridership than did the walkability of the area around the origin (Cervero, 2006). Cervero also noted the secondary benefits of inducing walking and cycling to transit stations (64% walked or biked to the station in this study). Schlossberg and Brown (2004) suggest that greater attention to the walkability around transit hubs needs to be made. They found that street networks varied considerably around stations in their study and that this had a significant impact on ridership.

In an excellent review of urban morphologies and their impact on AMNs, Cantell (2012) highlights the strengths and weaknesses of different forms. The popular grid pattern adopted by the New Urbanism movement reduces distances with shorter blocks but can contribute to increased traffic and peak times. The Greenway Neighbourhoods with their massive blocks, curvilinear roads and homes facing greenbelts offer more hospitable pedestrian pathways but fewer roadways for cars. In a similar vein, cul-de-sac neighbourhoods offer greater privacy but at the cost of increasing walking distances. This can be mitigated by a modified version called the fused grid. There are many variants but it resembles a mix of cul-de-sac and grid with muted advantages and disadvantages. Perhaps one of the most important accessibility elements of the New Urbanist model is the removal of sidewalk/driveway crossings.

2.3.4 Transportation Planning Models

Traditionally, transportation planning focused on building efficient systems that address the requirements of the automobile (Litman, 2012). The goal was to enhance auto *mobility* by reducing congestion, increasing capacity, providing more parking, etc. Other modes of transportation were either downplayed or dismissed altogether. An emerging approach is on improving *accessibility* by being attentive to the convenience of getting to and around a destination through a variety of modes (Blecic et al., 2013; Kwan et al., 2003; Lin et al., 2012).

Transportation Demand Management (TDM) or mobility management is an approach to addressing AMNs from a broader perspective. According to Transport Canada, TDM is the "…use of policies, programs, services and products to influence whether, why, when, where and how people travel…" (p. vii). Figure 2.5 highlights the integrated approach TDM makes incorporating economic, social, and physical factors to address transportation demand, supply, and land use concerns.

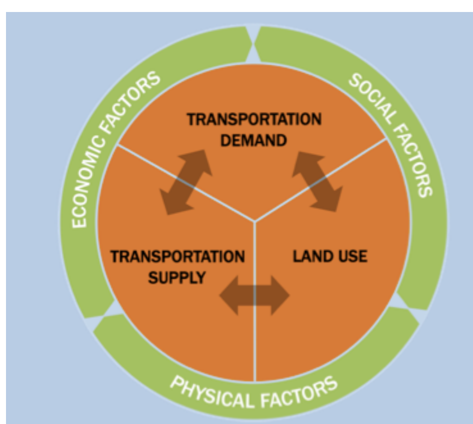


Figure 2.5 Elements of a community's transportation and land use system (Source: Transport Canada, 2012, p. 2.)

An important contribution from the transportation planning literature that is fitting to this study is the concept of transportation networks. In contrast to the urban planning models that characterize the urban experience as a product of compositional measures over land use areas leading to density and diversity metrics, transportation planning models are often about linked phenomena leading to dynamically networked structures and flows (Rodrigue et al., 2006). Rodrigue et al. (2006) characterize transport systems as networks of nodes and links that can be measured using the principles of Graph theory. In particular, link conditions impact the overall accessibility of the network. They differentiate absolute barriers - preventing movement with relative barriers - frictional forces that slow down circulation. Leveraging Graph theory, Rodrigue et al. (2006) are able to visualize and calculate the impacts different conditions have on the efficiency and effectiveness of the overall network. While their focus is on motorized transport, corollaries with the pedestrian environment offers great opportunities for operationalizing this approach. Blecic et al. (2013) utilize this approach in addressing walkability as a set of nodes (origins and destinations) connected by edges with constraint attributes. They use these fundamental structures to visualize and measure emergent networks and their capacity to meet the needs of users (i.e. utility functions).

A similar approach is used by Rubulotta et al. (2013) to measure the centrality of nodes in networks. They examine how different types of centrality (e.g. closeness, betweenness, and eigenvector centrality) can tell different stories about accessibility. While these measures are still in their infancy, they offer an approach that better mimics the pedestrian environment.

2.3.5 Other Planning Approaches

Other models, programs, and approaches exist, often with similar principles and objectives. For instance, Complete Streets is a program in which neighbourhood streets are designed for everyone including pedestrians, cyclists, motorists, and transit. They are designed and operated to enable safe access for all users and are a factor in enhancing physical activity (Moreland-Russell et al., 2013). It is unique in that it stresses inclusion of all users (including reference to disability legislation), street connectivity, and defining measures that fit within the context of that community (McCann & Rhynne, 2010). Healthy Communities is an initiative that emphasizes a democratic approach to addressing community problems. It focuses on continually improving the social and physical environments to accentuate a community's strengths (Hancock, 1993). Livable communities are places where homes are affordable, transportation is people-oriented, and there is broader access to clean, healthy parks and open spaces (Wheeler, 2001). Programs combating the existence of food deserts (neighbourhoods lacking access to healthy food options), ageing in place (enabling people to stay in their homes as they age), Safe Routes to School (allowing kids to walk and cycle to school rather than being dropped off and picked up each day) are just some of the approaches that have emerged over the past ten to twenty years. AMNs are key components to all of these approaches and accessibility plays a variable role in each.

2.4 Walkability Indices

A number of authors have combined travel behaviour correlates into a single, composite walkability score for an entire area (Frank et al., 2010a; Frank et al., 2006; Owen et al., 2007). An example of the factors included in a walkability index are "…dwelling density, street connectivity, land-use mix, and, net retail area" (Owen et al., 2007, 389). Badland et al. (2009) used street connectivity (intersection density), dwelling density, land use mix (entropy index), and retail floor area ratio (retail floor area/retail parcel area) to develop their walkability index (sum of four factors). Christian et al. (2011) warn that minor changes in how a measure is defined can have significant impacts on results suggesting that weighting of factors in these walkability indices makes a difference. They found that land use mix was especially sensitive to differences in measures.

In a different approach, Renne & Wells (2005) differentiate a pedshed (i.e., the sidewalks and shortcuts only available to someone walking) as a true representation of the ½ mile walking distance from the center of the transit station, as opposed to the typical ½ mile "air" distance used to define walking catchment areas in most studies. A public tool called WalkScore uses the 1-mile air distance to 13 common destinations to define walkability (Carr et al., 2010). Manaugh & El-Geneidy (2011) examined the results of using four different walkability indices on the same case study area (Montreal, Canada). Each method proved effective at explaining specific walkability contexts (e.g. WalkScore proved accurate for shopping while the pedshed approach worked well with associating travel choices to school travel). Across all approaches, socio-economic factors were also important to factors to include in the final analysis.

In order to evaluate walkability, many of these approaches use a variety of tools to assess the environment. Some walkability audits leverage geographic information systems while others rely on self-reported surveys. One frequently used tool, Neighborhood Environment Walkability Scale (NEWS), is a paper survey used to identify environmental correlates of physical activity based on perceived assessments of walkability factors (Saelens et al., 2003). The factors being assessed are in alignment with the studies reviewed in the mobility behaviour section and include: housing types, availability of resources (e.g. food market, hardware store, bank, etc.), topography, street and sidewalk characteristics, aesthetics, crime, traffic conditions, access to transit, social interaction, and route choice. The final question asks the participant to rate their level of satisfaction with a number of outcomes. A correlation between factors and satisfaction can be used to identify which variables are influencing satisfaction (Cerin et al., 2006).

The Irvine-Minnesota Inventory (Day et al., 2005) addresses many of the same variables as NEWS. It looks at features in the built environment that have links to walking and active living. This inventory measures the individual perceptions of destination accessibility, attractiveness, and safety from traffic and crime. Many more tools exist. Moudon and Lee (2003) reviewed thirty-one walkability instruments and grouped them into three categories based on trip purpose (i.e., utilitarian vs. recreation), route conditions (e.g. safety, sidewalk conditions, crosswalks), and broader area conditions (e.g. land use intensity, street networks). The spatial models used to assess the built environments in these tools were found to be inconsistent. Distance could be measured using straight-line measurements, street networks, or recreational networks. Many of these inventories had not been validated at the time of the review and many more have been developed since this review. An examination of these tools as it relates to PWDs will be examined in a subsequent section.

2.5 Current Status of PWDs

PWDs experience very different economic, health, and social realities as compared to the non-disabled population (and even within the disabled population itself). Despite the challenge of simply counting the number of PWDs and interpreting inconsistent data, basic trends in the status of PWDs with regards to health, social, and economic matters is unassailable (Fujiura & Rutkowski-Kmitta, 2011). Some of the difficulties in dealing with the data are because each country defines disability to suit their needs. These definitions may change over time, and social, political, and cultural norms may distort results. Another challenge in understanding these outcomes lies in the complex web of interconnections between them. Often, one indicator will reinforce another, spiraling individuals and communities into widening gaps of inequity. The next section will identify some of the key outcomes and indicators that highlight the current inequities that exist. The list is not meant to be exhaustive but sheds light on how far reaching the impacts are on PWDs.

2.5.1 Economic Status of People with a Disability

There are significant employment, income, and education indicators that point to a widening gap between PWDs and those without. For instance, Erickson and Lee (2008) found that employment rates in the United States for PWDs are only 36.9% (21.2% full time) compared to 79.7% for able-bodied Americans. Similar findings elsewhere illustrate that someone with a disability is 2 to 3 times more likely to be unemployed than someone without a disability (Zarocostas, 2005). PWDs are also more likely to engage in non-standard employment (e.g. contract work) that is lower paying and offers fewer securities (Schur, 2002). Even during the economic expansion of the 1990s, PWDs did not seem to achieve comparable employment gains as their non-disabled peers (Thomas & Barnes, 2010). Fortunately, the disparities in Canada appear to be less drastic than in the United States and elsewhere (Brown & Emery, 2010) though conflicting data from the International Disability Rights Monitor (International Disability Rights Monitor, 2004) states that PWDs have a five-fold higher rate of unemployment.

Considering the nature of the employment situation, it is not surprising that Erickson and Lee (2008) found that family income levels are much lower ($34,000 compared to $61,000) and poverty levels are much higher (24.7% compared to 9.0%) in the United States for PWDs than those without. The disparities, however, are not the same across all disabilities. Those with more severe disabilities experience a greater than 50% reduction in earning compared to 21% for those with mild disabilities (Thomas & Barnes, 2010). These dire economic measures may be attributable to fewer working hours working in lower paying jobs. For those who do find work, Brown and Emery (2010) found an earnings penalty of 21 to 50% depending on the nature of the disability. A study from Europe found that the cost of living is higher for PWDs, putting an even greater strain on limited finances (Cullinan et al., 2011). Based on research done in Ireland, Cullinan et al. (2011) estimate that there is a 30% premium, directly attributable to disability-related costs for families that have someone with a disability in them. These studies do not even take into consideration costs that arise from the fact that supply and demand dynamics are distorted (e.g. low supply of homes that have full accessibility features) inflates costs of living.

The World Health Organization (WHO) documented in their World Report on Disability (2011) lower education levels for PWDs and Roulstone (2012) uncovered higher school dropout rates. Higher education is not a guarantee of employment either. In the U.S., employment rates for PWDs with a college degree are only 50.6% versus 89.9% for their able-bodied peers (Bureau of Labor Statistics, 2012). For those that do manage to find employment, opportunities for advancement are limited (Roulstone, 2012).

The costs of disability are not borne by the individual alone. An Australian economic analysis study estimated that a $43 billion opportunity was being lost because of the gap in employment rates between people with and without disabilities (Deloitte, 2011). In the United Kingdom $27 billion could be added to the economy if employment rates were higher for PWDs (Disability Rights Commission, 2007).

Other community costs take the form of lost opportunities, particularly in terms of tourism potential. Globally, PWDs have over $1 trillion in buying power ($220 billion a year in North America) with $81.7 billion that could go into accessible travel (Open Doors Organization, 2002). A 12% increase in hotel revenues was reported after the Americans with Disabilities Act was passed in the United States. Despite this, tourism-related businesses continue to resist making changes to accommodate this market opportunity.

2.5.2 Health Status of PWDs

Disparities in health status are also quite telling (Reichard et al., 2011). It was found that the more severe the disability a person had, the shorter their life expectancy (Thomas & Barnes, 2010). The CDC documents PWDs as having nearly three times the incidence of poor health (37.3% versus 12.8%) compared to the non-disabled population (Ewing et al., 2003). This translated into a number of deficits for PWDs. Rates of heart disease were nearly triple (10.5% versus 3.8%), diabetes double (13.6% versus 7.0%), and almost twice the rates of obesity (36% versus 21%) for people with versus without disabilities. A caution should be made that many studies that use BMI as their standard for health under-predict obesity for people with spinal cord injuries due to the loss of neuronal activity and less lean body mass. In one study, using a BMI of 30 to define obesity failed to identify 73.9% of actual obesity in people with spinal cord injuries (Laughton et al., 2009). One in five adults reported difficulty walking 2 to 3 blocks unaided, and their odds of engaging in regular interpersonal interaction was almost 50% lower than those without difficulty walking (Clarke et al., 2011). Also, average blood pressure was 50% higher, likelihood of arthritis three times higher, and asthma 5.5 times as likely for someone with a disability. Even injury rates were higher for the disabled population.

These findings may be attributable to the fact that 17.6% of PWDs do not participate in any physical activity versus 9.5% of the non-disabled population who do not. Activity recommendations, such as 30 minutes of walking per day fail to consider the fact that energy expenditure is significantly less for someone using a wheelchair than someone walking. In fact, overall life satisfaction and mental health was lower for PWDs than for the non–disabled population. For people with chronic disabilities, subjective well-being was much lower in most countries because of a lack of real and perceived personal supports (Croft et al., 2013).

In addition to this, health care costs due to disabilities are substantial and rising. Costs for older people are $3919 higher if that person is unable to walk according to Webber et al. (2010). These authors stress the importance that mobility and independence have on health status and quality of life. Guralnik et al. (2002) found that an additional $26 billion annually is needed in health care to address the needs of newly disabled older people. Emerson et al.

(2011) note that health care services such as clinics, doctors, and dentists are less frequented due to economic and environmental factors. Preventive measures like this are important for avoiding disability in the first place as well as escalating costs to individuals and the community as a whole.

These authors also stress the importance that mobility and independence have on health status and quality of life. All of these statistics reinforce the potential benefits that can be had if accessibility of the physical infrastructure facilitates greater mobility in the AT environment (CDC, 2013).

2.5.3 Social Status of PWDs

Promotion of accessible and inclusive communities contributes to a better quality of life for PWDs. By being more accessible and inclusive, PWDs will gain many personal benefits. Research has shown that all PWDs are not experiencing these outcomes equally. Women with disabilities face higher levels of physical abuse (inside and outside the home) than men with disabilities (Emmett & Alant, 2006) and children with disabilities are bullied more than their able-bodied peers (WHO, 2012). Generally speaking, feelings of being disempowered, lacking control and not being tapped into the 'social web' have all been identified (Shields et al., 1998; Emerson et al. 2011; Green et al., 2005; Milner & Kelly, 2009; Arneil, 2006). In the U.S., (Schur & Adya, 2012; Schur et al., 2002; Shields et al., 1998) have shown that voting rates are 15 to 20% lower for PWDs. Fekete & Rauch (2012) and Nosek et al. (2001) found that, for people with spinal cord injury, activity levels drop off after injury and with it, quality of life. The fact that PWDs feel stigmatized and marginalized in their own communities has even spilled over into the virtual world, where they use the Internet 50% less than the non-disabled population (Vicente & Lopez, 2008).

Even basic needs like housing and transportation exhibit significant gaps. These were key issues in the disability rights movement of the 1960s and 1970s. The push to de-institutionalize PWDs and return them to their community became a priority. However, affordable housing choices were not available. Baby boom economics at this time didn't persuade accessible housing construction. In the United States demand for an estimated 33.2 million accessible homes by 2050 needs to be met (Smith et al., 2008; Smith et al., 2012).

Not surprisingly, transportation has been identified as a significant issue for PWDs (Aldred & Woodcock, 2008). In the United Kingdom, only 40% of people with a disability have a household car versus 73% of the general population. For those without a car, it is telling that two thirds of PWDs in the U.K. are dissatisfied with walking conditions and that 50% would walk more if improvements were made. As Americans age, Keysor et al. (2009), found that activity levels dropped significantly in neighbourhoods with mobility barriers.

2.5.4 Demographics

The previous section demonstrates the vast inequities that exist between those with and without disabilities. This section will build on this by defining the magnitude and heterogeneity of the population affected. Census data is relied upon to quantify the number of people that experience the outcomes discussed previously. Collecting, counting, and reporting disability statistics is not an exact science. Because of differences in data definitions across political borders and over time, conclusions from any single report need to be tempered. Despite this challenge, the magnitude of the disability population is evident. The number of people with a disability has now surpassed 1 billion worldwide or approximately 1 in every 6 people (World Report on Disability, 2011). There are 80 million people in Europe (European Disability Forum, 2010), 56.7 million people in the United States (Brault, 2012), 4.4 million people in Canada (14.3%), and 639,000 people in British Columbia (Statistics Canada, 2012) with a reported disability. For the majority of developed nations, disability rates range between 10 and 20 percent.

In some nations like Canada and the United States, relatively accurate information is available in even more granular categories. A further breakdown by disability type, age distribution, and gender distribution is presented below to emphasize the heterogeneity even within the disability population. With changes to Canadian policies in progress, it is difficult to determine if future data will be as useful and/or comparable as the census surveys have been for researchers and marketers over the years.

The types of disabilities Canadians have cross a broad spectrum. Table 2.1 represents the major disability categories (hearing, mobility, agility, visual, communication, learning, psychological, and pain). There is additional breakdown for those over 65 in Canada and British Columbians with a disability. Nearly all categories have seen an increase between the 2001 and 2006 censuses. In some cases, people may have multiple disabilities that account for any discrepancies in the sum of disability types and the total number of people with a disability.

Table 2.1 Disability types in Canada (Source: Statistics Canada, 2007)

Disability Type	In Canada	Over 65 in Canada	In B.C.
Hearing	1.29 million	735,000	197,000
Mobility	2.95 million		423,000
Agility	2.86 million		393,000
Visual	840,000	368,000	111,000
Communication	560,000		72,000
Learning	750,000		107,000
Psychological	650,000		106,000
Pain	2.97 million		428,000

In addition to disability type, the 2006 Physical Activity Limitations (PALS)[1] census broke down disabilities into mild, moderate, severe, and very sever levels. The findings were: 1.55 million with a mild disability, 1.09 million with a moderate disability, 1.55 million with a severe disability, and 601 thousand with a very severe disability (Statistics Canada, 2006).

Other information that is valuable to understand is incidence of spinal cord injury. In Canada, approximately 85 thousand people are living with a spinal cord injury with 4300 new injuries annually. Of these, 48 thousand are paraplegics and 37 thousand are quadriplegics with a majority being between the ages of 40 and 79 (Farry & Baxter, 2010). Many of those with spinal cord injury end up using wheelchairs or other mobility devices to travel.

e) Disability by Age

As people age, the prevalence of disability clearly increases. People may be living longer lives but the number of healthy years they experience may be decreasing (Peremboom & van

[1] Because of a change in policy by the ruling government in 2010, the future availability and quality of disability data is uncertain in Canada (Roman, 2010).

den Bos, 2005). Robine & Kitchie (1991) found that men could expect 6 years and women 9 years of their final years with a disability. In Canada, 1.76 million people over the age of 65 have some kind of disability representing 43.4% of this demographic of which 1.02 million are over 75 years of age (Statistics Canada, 2012). In British Columbia, 47.2% of those over 65 have a disability and 57.5% of people over 75 have a disability. This is just a snapshot of disability in time. The dynamics of disability based on other factors are important as well.

For instance, the experience of disability will be very different when considering time of onset - congenital (from birth) or acquired later in life. Jamoom et al. (2008) found that those who acquire disabilities early in life have better health outcomes than someone that has spent a significant amount of their life without a disability. Seniors who acquire a disability much later in life will have very different perspectives on their environment and may need to develop a new network of resources to address environmental challenges. Other challenges like mental health, cognition, memory, pain, and progressive disease/disability are complex factors to consider (Jamoom et al., 2008).

f) Disability by Gender

An often-overlooked aspect of disability statistics is the difference in gender. Women are overrepresented in the disability category later in life. This is true because women live longer lives but they also have higher rates of disability even for the same age groups as men. 2.02M million Canadian men (13.4%) and 2.39 million Canadian women (15.2%) have a disability in Canada. The numbers are slightly higher in British Columbia where 290 thousand men (14.8%) and 348 thousand women (17.1%) have a disability. For those over 65 with a disability in Canada, 744 thousand are men (42%) and 1.01 million are women. The gap widens over 75 years of age where 397 thousand men (39%) have a disability versus 621 thousand women. The numbers in British Columbia are similar where 114 thousand men (44%) have a disability versus 143 thousand women (56%). 63 thousand men over 75 (43%) and 85 thousand women (57%) have disabilities in British Columbia.

g) Trends and Implications

In Western countries, demographic indicators point to an ageing population that is becoming more reliant on a shrinking working age population (Chawla, 1990). This is referred to as the dependency ratio and it has significant implications on social and economic conditions. As the demand rises, the ability of communities to support initiatives that can enhance accessibility is compromised. When dependency ratios increase it becomes more challenging to act strategically regarding accessibility. Statistics Canada reported an increase in the percentage of people reporting a disability from 12.4% in 2001 to 14.3% in 200 with an increase of over three-quarters of a million people in five years (up from 3.60 million or 12.4%), 1.02 million over 75 (397 thousand men and 621 thousand women).

The societal response to the status of PWDs has changed drastically over time and continues to struggle today. In order to put this into context, the following section will recount the debate about what disability and how it has been characterized over the years. This helps to inform a path forward that better embodies the needs and preferences of PWDs.

2.6 Bridging the Accessibility Gap

Oliver (1990) writes that the disability studies field has obsessed over defining disability, impairment, and handicap at the expense of theoretical substance. Since 1990, this has not changed much. This is evident in the fact that broader sociological enquiry has not been informed by the field of disability studies. The object of this study is not to focus on the broader discourse on disability but to address the basic challenges facing PWDs in their daily lives. By adopting a social ecological approach to this problem, it is hoped that a new theoretical framework will lead to practical change in the urban environment.

Disability studies are a relatively new area of formal research (Braddock, & Parrish, 2001). The main discussion in disability studies has revolved around defining disability through medical and social models. It is only recently that advances like the bio-psychosocial model and critical disability studies have started to question this rigid dichotomy (Mackelprang, 2010). It is very important to understand the disability models as they inform urban planning theories and practices.

2.6.1 Medical/Individual Model of Disability

The medical (or individualized) model of disability posits that a person's impairment is the locus of their disability (see Figure 2.6). Impairment is a physical, cognitive or mental challenge that is a result of a biological complication. Impairment could be an amputation, spinal cord injury, hearing loss or loss of vision for example. In the medical model, if impairment can be fixed or cured then the person can be made "normal" again. With this model, all attention is put on fixing the person rather than addressing deficiencies in the environment. This approach contributes to a lack of knowledge about accessibility challenges in the physical environment.

Health Condition → Impairment → Disability → Handicap

Figure 2.6 Traditional model of the disablement process .(Source: WHO, 1980)

The medical model limits the available solutions to those that are outside the domain of urban planners. Because of this, more time and financial resources have gone into trying to find cures than improve environmental conditions. The medical model, in essence, ignores the issue of disabling environments and fails to provide urban planners with a role in improving the quality of life for PWDs.

2.6.2 Social Model of Disability

The radical movements of the 1960s and 1970s included a vocal disabled community demanding greater equity and justice. In Britain, Oliver & Barnes (2010) describe how this activism brought about a re-orientation of the disability model. The social model emerged as a clear and distinct rejection of the medical model. Disability was no longer a product of some personal tragedy but the result of social and environmental conditions imposed by a society that sought to marginalize them (see Figure 2.7). The social model in Europe and, in a muted form, North America took hold. By the 1990s, the social model had inspired disability rights legislation such as the Disability Discrimination Act (DDA) in the United Kingdom and the Americans with Disabilities Act (ADA) in the United States.

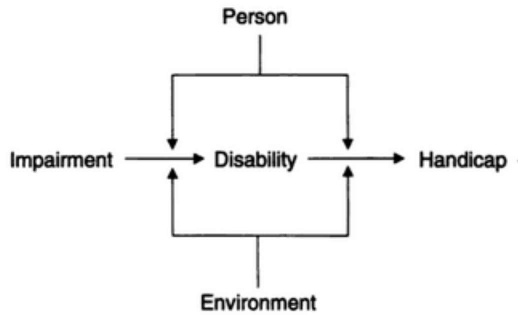


Figure 2.7 Social model of disability.(Source: Steinfeld & Danford, 1999)

It has been nearly twenty-five years since the social model arrived and many researchers feel it is time to re-examine its fundamental principles. There are researchers now who feel that disability is a combination of both impairment and environment (Hughes & Paterson, 1997). The two should not be considered as separate but reinforcing realities. Shakespeare & Watson (2002) believe the emphasis on the environment that the social model made was useful during the infancy of the disability movement, but needs an overhaul today. In the end they poignantly state, "…there is no qualitative difference between PWDs and non-PWDs, because we are all impaired" (Shakespeare & Watson, 2002, p. 27). There is no doubting, however, that the social model has made a great impact on the lives of PWDs and continues to inform policy.

2.6.3 Challenging the Social Model

There are a number of models being explored by the disability studies field that draw on broader social and political theory. The bio-psychosocial model is rooted in an ecological perspective of the community as discussed previously. This is one in which a number of personal, social, political, and physical factors, working at multiple levels, effect behaviour. By considering the problem from this more interdependent perspective, it is hoped that more robust and sustainable alternatives can be identified. Paez & Farber (2012) draw on the social-ecological model (Figure 2.8) to connect well-being and mobility with the broader consequences resulting from exclusion.

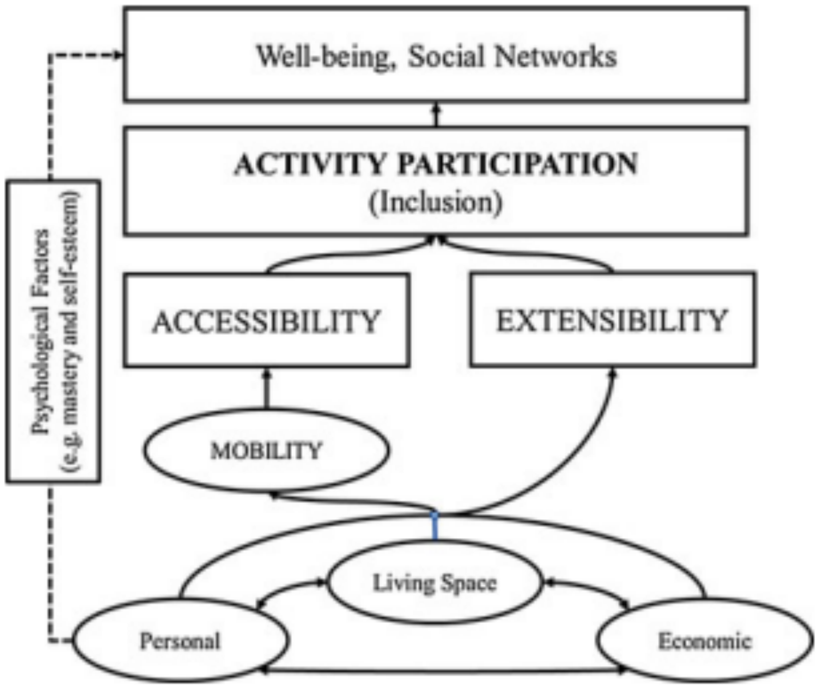


Figure 2.8 Mobility and social exclusion: a conceptual framework for mobility. (Source: Paez & Farber, 2012, 1058)

Another stream of research initiated by Golledge (1996) discusses the "geography of disability" and examines the physical aspects of accessibility in great depth. It has motivated literature in the disability studies field that is more spatially oriented than the philosophical debates around disability models (Chouinard, 1997; Chouinard, 2001; Gleeson, 1996; Golledge, 1993). Feminist theory, critical studies (Thomas, 2007), and psychosocial approaches (Shakespeare & Watson, 2002) are also being leveraged to explore the embodiment of disability.

The view of disability adopted by planners will colour the choices they make. A strict medical model view would remove all responsibilities to build more accessible communities. On the other hand, adopting a strong social model approach might fail to be economically responsible to the entire community.

2.7 Needs and Preferences of PWDs

PWDs have unique physical requirements as compared to the able-bodied population, yet many of the same desires and preferences for experiences in their physical and social environment. The following will look at both sides of the challenge – from the perspective of the individual and the environment. The individual perspective is examined through anthropometric and kinematic findings, mobility aid factors, and psychosocial research.

2.7.1 Anthropometrics, Biomechanics, and Kinematics

The physical needs of PWDs can be approached through anthropometric, kinematic, and biomechanical studies. Anthropometric studies concentrate on the parameters that define the physical capabilities of an individual (Steinfeld et al., 2010) while kinematic and biomechanical studies examine bodies in motion. Bradtmiller (2000) found a lack of studies focusing on PWDs and limited consistency of measures across studies that were undertaken. Studies focusing on wheelchair users are often done with participants at rest or traversing short distances in laboratory environments. This approach brings into question applicability to real world environments. Additionally, studies that have informed urban planning tend to use the abilities of the 95% percentile as a design goal, which usually rules out the needs of many PWDs (Steinfeld, 2002). Urban planning policies and practices, therefore, model designs and policies have relied on data that represents the measures and abilities of the average, able-bodied citizen.

Variability between disability types is a significant challenge as well. Paquet and Feathers (2004) make note of the range of measures (in particular seating height and sightline height) differing between manual and power wheelchair users as well as gender. More recent work from the Inclusive Design and Environmental Access (IDEA) labs has been used to update ADA guidelines in the United States (Steinfeld et al., 2002). The IDEA study provides some basic measures for reach, height, and clear floor space required for wheelchairs (see Appendix A for detailed measures). An important finding from this study was that overreliance on able-bodied people acting as fill-ins in these studies has led to inaccurate findings. They also noted a need to integrate anthropometric and kinematics for getting more realistic results.

Kinematic studies that incorporate real world conditions are even harder to find. In one study, Steinfeld and Danford (1999) found that 60% of 56 wheelchair users could wheel up a 5% slope for more than 30m. Richter et al. (2007) demonstrated that manual wheelchair users needed 2.3 times more power to on a treadmill with a 6% cross slope. Hurd et al. (2009) discovered that different textured surfaces and 3% slopes increased the effort required by a manual wheelchair user and often resulted in the dominant arm carrying a greater degree of the load.

2.7.2 Mobility Devices

Mediating factors in enabling (and often disabling) accessibility are technologies and mobility devices like scooters, wheelchairs, hand cycles, power assisted doors, and elevators. Mobility devices will change the width of space required, eye level height, centre of gravity and a number of other attributes. A breakdown of the usage of different mobility devices is shown below (see Figure 2.9).

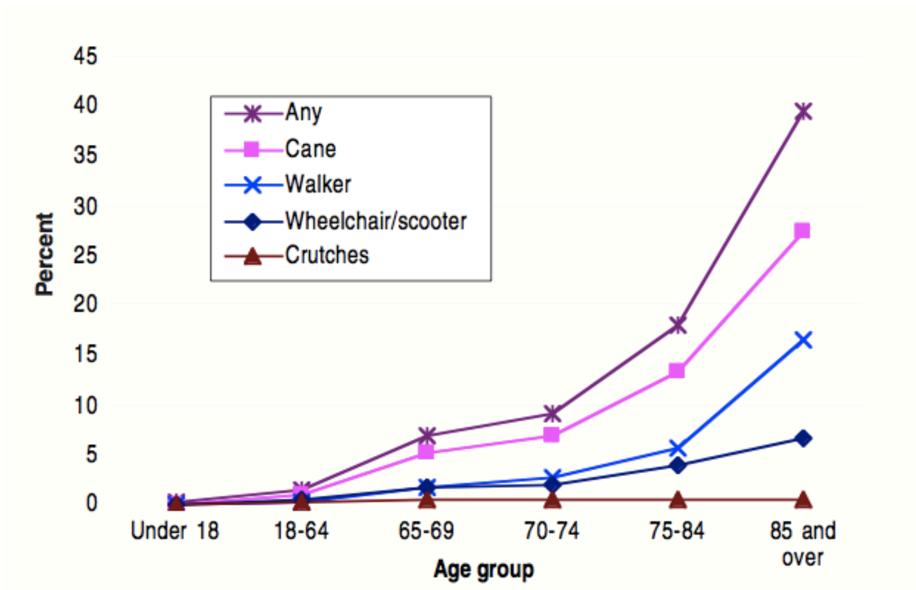


Figure 2.9 Proportion of population using mobility devices, by age and device. (Source: Kaye et al., 2000)

The structural dimensions of wheelchairs play an important part in the experience of a PWD. Wheelchairs themselves can range from as light as 15 pounds for a manual wheelchair to several hundreds of pounds for power scooters. Scooters, for instance, risk tipping over at curbs with greater slopes and causing harm because of their weight higher centre of gravity than a manual wheelchair (Jancey et al., 2012). New technologies like assistive propulsion devices can increase distances, overcome greater slopes, and even adjust to cross slope conditions. Front casters and devices like the FreeWheel (a large wheel attached to the front end of a chair that lifts the front castors up, see Figure Figure 2.10) or special beach chairs can reduce the impact obstacles and surfaces play.

Figure 2.10 FreeWheel. (Source: http://www.freewheelcanada.com)

There are costs and benefits for all of these technologies. Depending on policies, many of these technologies can be expensive for individuals and organizations. Building an elevator provides greater access but comes at a significant cost. Sometimes the technology itself has costs and benefits. Mobility scooters allow for great ease in traveling outside but are often difficult to manoeuver in tight spaces or transport with cars. Anti-tip devices at the back of wheelchairs prevent falling backwards but make it difficult to perform even a small wheelie to overcome an obstacle. In addition, some technologies may be stigmatizing even when they provide significant benefits. A beach chair may be the only way to make your way across a sandy beach but it will definitely draw attention to the user.

2.7.3 Psychosocial Factors

In extensive studies by 2010 Legacies Now (2009), Keroul (2001), and the Harris Report, PWDs were shown to seek out the same activities and travel destinations as their able-bodied counterparts. These studies also point out the numerous challenges that had to be overcome in order to travel away from home. A lack of information contributed to this, bringing about an uncertainty about a person’s own ability to participate in the experience. Even perceptions about the accessibility of the local community can have a significant impact on activity levels (Humpel, 2004; Leslie et al., 2005; Shigematsu et al., 2009; Strath et al., 2012).

In the community context, studies like Bromley et al. (2007) provide information about the perceptions and realities of urban form on accessibility in the urban core. Their research uncovered that perceived accessibility decreases the further away from the city centre a person gets. They suggest policy changes, disability awareness programs, improved public transit, and some compromise from disability advocates to cope with this challenge.

2.8 Environmental Constraints

The research on urban and transportation planning models makes little or no mention of the PWDs. The principles and measures they use to guide planning decisions do not take into consideration the needs and preferences of PWDs (Seekins et al., 2012). Where research has been done, it has focused mainly on buildings and not the connections between them. The consequences of these gaps brings into question whether or not purported benefits to the general population will trickle down to PWDs. Economic, educational, and health findings suggest the benefits are not being felt equally.

Many studies have looked at the specific environmental features that fail to meet the needs and preferences of PWDs (Kaye et al., 2000; Steinfeld & Danford, 1999). Evans (2009) provides a review of existing assessment tools and a list of macro and micro-level elements that need to be assessed. Kaye et al. (2000) identified doorways, ramps, railings, parking, and bathroom dimensions as issues in the home as challenges most identified by users of mobility devices. A further 82% reported that transit was difficult to get to and 66.9% found transit difficult to use. Steinfeld et al. (2010) findings showed that PWDs' physical requirements often exceeded many of the standards that inform the ADA Guidelines. Kirchner et al. (2008) interviewed participants to get their perceptions of how the impact barriers had on their ability to get around their neighbourhood. Sidewalk conditions were overwhelmingly mentioned.

Church and Marston (2003) highlight a number of environmental constraints that influence route accessibility including path conditions (e.g. path surface, slope, crossings, obstacles, safety). Disability legislation such as the ADA and standards like Canadian Standards Association 651-04 inventory address many of the environmental constraints that exist in the physical environment. Parking spaces, entrances, public washrooms, seating, signage, etc. are just some of the features covered in the built environment. Other research like Kockelman et al. (2001) critique path cross slope as being too restrictive though other studies cited found very different results. In Canada, the proposed cross slope standards for the AODA (2005) stick with the traditional maximum of 2%.

2.8.1 Accessibility and Inclusion

Accessibility is a term used in different ways in different fields. It is important to differentiate accessibility and mobility as it is used in transportation planning literature and how it is used here and in disability studies literature. Transportation planning literature defines mobility as the efficient systems that allow people to go from point A to B and accessibility as the ability to get around at the destination. In this study **accessibility is the point at which the constraints of the environment do not exceed the abilities of the individual.** This can be applied to the path from A to B or the ability to navigate at point B. In essence, accessibility is a line and node quality whereas it only speaks to the ability to move around at the destination in transportation planning.

Therefore, accessibility is demonstrated through the ease with which people can move around their homes and communities, through accessible building design, signage, housing and transportation. Accessibility isn't a quality of a path or feature on its own but dependent upon the individual that is doing the accessing. This can be best explained by defining absolute versus relative access. An absolute access demand is a barrier that a person cannot overcome due to their individual capacities. An absolute barrier for a person in a manual chair might be a path with a slope greater than 8.3%. Relative access is a measure of the added burden a feature presents. It is usually an accumulation of these measures (either concurrently or cumulatively) that make an asset or link unmanageable. All individuals have limits on the burden (available physical, social or economic) they are willing to manage.

Inclusion builds on top of the accessibility layer and represents the opportunities and experiences within the physical environment. Inclusion is defined by the degree to which all individuals can experience an opportunity. Inclusion is influenced by the policies and practices that actuate the opportunity. This includes human resource practices (hiring, training, orientation, reward, etc.), policies (rules and regulations, processes (design of services, fulfillment, etc.) and practices (communications, promotion, emergency procedures, etc.).

2.8.2 Accessibility Policies

In Canada, the Human Rights Act ensures that no person would be discriminated against on the "…race, national or ethnic origin, colour, religion, age, sex, sexual orientation, marital status, family status, disability…". In the United States, the Americans with a Disability Act

(ADA) also protects civil rights but goes further by establishing standards for the built environment – 2010 ADA Standards for Accessible Design.

Legislation like the Accessibility for Ontarians with Disability Act (AODA) and Americans with Disability Act (ADA) guide the development of accessibility compliance standards through urban planning tools like site plans and building codes. The Canadian Standards Association has a number of standards that apply to the built environment (CSA B651-04 Accessible Design for the Built Environment and Z614-07 for Children's Playspaces) but it is up to the provinces to lead the accessibility challenge (including monitoring, evaluation, and enforcement).

In Canada, only the province of Ontario has legislated accessibility measures in this way. The first two AODA standards became law in 2010 and 2012 but they only address customer service. Employment, transportation, and information standards are planned to take effect in 2021. More significant built environment standards are still not law and their incorporation is yet to be determined (Ontario, 2006). Currently, British Columbia (the proposed case study location) has no explicit accessibility legislation and none is in the works.

Traditionally, compliance based institutions have been responsible for creating standards (ADAG, CSA, and ISO) and have become the de facto characterization of the built environment. These standards are often developed through biometric studies done in the laboratory. They do not necessarily reflect how this works in the real world and are slow to respond to new demands. As well, these standards are unevenly applied when translated into building codes that make allowances for construction dates or heritage status.

In reviews of U.S. and Canadian approaches to accessibility and inclusion, Burns & Gordon (2010) and Rhoads (2010) identified significant differences between the two. Because the U.S. has national level legislation, greater consistency is found from one state to the next. The same cannot be said about Canada where disparities and inequities across the provinces (Council of Canadians with Disabilities, 2005).

There are a number of accessibility standards for the built environment borne from advocacy efforts in the 1960s and 1970s (Burns & Gordon, 2010). These standards are often fine-tuned through biometric studies done in the laboratory. This approach does not necessarily reflect how accessibility plays out in the real world and is slow to respond to technological and environmental changes (e.g., motorized scooter use by seniors is on the rise and their large dimensions are not accounted for in regulations). As well, these standards are unevenly applied when translated into building codes (e.g., date of construction or renovation often determines which accessibility standards must be met). Going beyond mere compliance standards is another consideration.

A recent advancement, universal design, is an attempt to go beyond compliance standards with its 7 principles (see Appendix B). Prescott (2012) and Steinfeld (2006) cautions that universal design eschews better design but still lacks operational measures to be useful to urban planners. The principles of universal design have been applied more to products like spoons or doors than at a larger scale. There are efforts under way to develop principles of universal design at the neighborhood level at the Center for Universal Design in North Carolina. The concept of continuity, or a seamless environment in which an experience is not hindered by barriers is an important principle (Maynard, 2009). However, Bringolf (2012) suggests that, ultimately, universal design is just a myth. As it has evolved, universal actually means accessible and is designed for PWDs - not for a universal audience. Indeed, Maynard (2009) suggests that the ambiguity in terms across disciplines around the term accessibility obfuscates its role in urban and transportation planning.

2.8.3 Accessibility Audits

To date, most audit tools and indices do not consider the needs and preferences of PWDs (Andrews et al, 2012; Clarke, 2005; Clarke et al., 2008; Farber & Paez, 2010; Gray et al., 2012; Paez, 2010). Seekins et al. (2012) claim that currently, "…no standard methods exist for assessing a community's accessibility or for accumulating such data across communities" (p. 270). In their study, Clarke et al. (2008) found a significant difference (4 times) in the walkability of poorly maintained streets between those with minor or no physical impairment versus those with more significant impairment.

Pedestrian Level of Service (PLOS) is one interesting way of measuring of the conditions, facilities, infrastructure, and furniture on a street. Traditionally PLOS focused on automobiles and graded the transportation network capacity from A to F. More recently, a modified PLOS incorporating the needs and requirements of PWDs has been developed (Asadi-Shekari, 2013). The authors describe the failures of previous attempts that simply applied the measures used on automobiles to people on sidewalks. This evolved into more robust assessments that included safety, convenience, continuity, and aesthetic variables. Other models have used measured discussed in the section on the principles of walkability. A key criticism according to the authors is the scale at which these measures were made. More micro-level measures are needed for addressing the needs of PWDs.

The ADA and the guidelines that followed helped to spur accessibility assessments by government agencies in the United States. The Access Board, in particular, provided standards that were easy to convert into accessibility checklists such as their own Facilities Checklist (ADA, 1995). In fact, hundreds of accessibility assessments have been developed since that time.

The tourism industry has been the source for a number of these in a number of countries. In Canada, Keroul, a government-funded agency in Quebec, charges businesses to get assessed at rated for marketing purposes. British Columbia assessed over 5000 businesses prior to the 2010 Winter Games and marketed this to countries around the world. This has transformed into Planet, a web application for rating business accessibility. European countries have come together to form ENAT (European Network for Accessible Tourism) to co-market accessible tourism opportunities there. The focus of all of these assessments is on single business properties, not paths and sidewalks.

2.9 Limitations and Gaps in the Literature

Despite the volume of research, there are a number of limitations in the literature. To date, most of the studies conducted have utilized cross-sectional methods only (Ewing et al., 2003; Giles-Corti & Donovan, 2003; Hoehner et al., 2005; Saelens & Handy, 2008). Bauman et al. (2002) believe researchers need to use different research design to meet this challenge. Without longitudinal studies, going beyond correlational claims will be difficult to achieve and policy decisions are minimized (Boarnet & Sarmiento, 1998). Badoe and Miller (2000) go on to say that the link between urban form and behaviour is still in question because of these limitations.

Self-selection bias is another confounding factor for making the link between urban form and PA (Ewing & Cervero, 2010). Some believe that physical activity may be higher in neighbourhoods exhibiting walkability features because people that are active move into these areas while others authors have found that self-selection had minimal impact on findings (Chatman, 2009). Regardless, researchers need to find innovative ways to create control groups to remove this bias from their results.

For this research study, the biggest limitation, and subsequent gap, is the explicit exclusion of PWDs in the studies done so far (Andrews et al., 2012; Asadi-Shekari et al., 2013). This brings into question making the findings generalizable to the disabled population. In research using population samples, many of the studies exclude those with "chronic conditions" to which PWDs would be classified. The principles and measures they use to guide urban planning decisions do not take into consideration the needs and preferences of PWDs. Where research has been done, it has focused mainly on buildings and not the connections between them. The consequence of these gaps is that generalizing the principles, measures and models discussed so far is hazardous. The purported benefits to the general population are not proven for the disabled population. Economic, educational, and health findings overwhelmingly suggest the benefits are not being felt equally.

2.10 Conclusion

The literature review highlights that AMNs hold great promise for addressing social, economic, health, and environmental benefits. The development of their underlying principles offer planners guidelines for designing communities that can offer greater accessible transportation and recreation opportunities. In identifying density, diversity, and design, they have drawn attention to the failures of sprawl. However, the ability to generalize this to the disabled population has not been demonstrated. For the 15 to 20% of the population with a disability and the communities they live in, this is problematic.

The gap in the literature regarding the role of PWD within communities and their utilization of AMNs needs to be addressed. The research will show where these gaps arise and offer an alternative approach for understanding the challenge.

3 RESEARCH DESIGN AND METHODOLOGY

3.1 Research Design

The literature review has validated the need for the research by showing the impact poorly planned active mobility networks (AMNs) can have on PWDs. It showed that the social, economic, and health statuses for PWDs are inferior to the rest of the population. The physical barriers in active mobility networks (AMNs) and needs and preferences of PWDs have been identified. Both research and accessibility policies differentiate the needs and preferences of PWDs and the environmental constraints they face. Urban planning and transportation theory gaps have been identified and their principles and measures explored.

Moving forward, policies in the case study areas will be compared against the needs and preferences of PWDs. In order to address the second research question, a case study methodology will be employed. First, however, the social topography model is introduced as a response to the shortcomings of existing models described in the previous chapter. The model borrows from emerging network models described in the section on transportation planning. This model will be used to assess the case study areas.

Research Question #2

2. What does the AMN look like from the perspective of a PWD?
   - How well connected are people to daily activities by the network of sidewalks, paths and trails?
   - How do these AMNs compare across disability types and to those of the able-bodied population)?

To understand how these principles, policies, and practices fail to incorporate the needs and preferences of PWDs, a case study approach will be used. Accessibility audits of pathways around 3 major transit hubs in the Lower Mainland of BC will be conducted in order to describe the embodied nature of accessibility. Ability Profiles of four ‘model’ users (described later) will be defined and inputted into the model:

- A person without a disability
- A person who is a paraplegic and uses a manual wheelchair
- A person who is a quadriplegic and uses a manual chair
- A person who uses a scooter

The data collected will help quantify and visualize the accessibility challenges for someone to travel from a defined origin to a number of nearby destinations. This study will use an exploratory, descriptive multi-case study of pathways (e.g. paths, trails, and sidewalks) between a central transit hub and dispersed resources and residences (e.g. restaurants, recreation centres and city hall). Before describing the case study sites, an introduction to the social topography model is provided. The model will serve to incorporate the needs and preferences of PWDs into a networked vision of the physical and socio-economic nature of the community. This will inform data collection, analysis, and conclusions.

3.2 Social Topography Framework

The framework proposed is informed by the needs, preferences, and environmental constraints faced by PWDs discussed previously. In particular, it leverages the social ecological model to describe the challenge of developing AMNs for everyone. Ideally, the model can reach out to all populations and their needs and preferences. This theoretical framework draws upon contributions primarily from network analysis (both social network analysis and transportation network research) to provide a starting point for its structural formation and disability studies to define its functional attributes. Unlike the policies and standards discussed in the literature review, this framework is descriptive and not prescriptive in nature.

The model proposed, social topography (see Figure 3.1), is defined as the **network of linked opportunities embedded into the physical and socio-economic fabric of the community.** Social topography is where citizens live, work, learn, play, socialize and tourists visit and recreate. The structural dynamics of these networks influence the potential capital (i.e., opportunities to engage fully) that is available to an individual. Decisions made in the urban planning and design process mold the emerging urban network structure and are managed by private and public institutions. With this framework in place, a comparison of AMNs based on varying abilities (i.e., Ability Profiles) can be made. At this stage, the measures introduced are initial attempts to quantify the social topography and will require further research to refine.

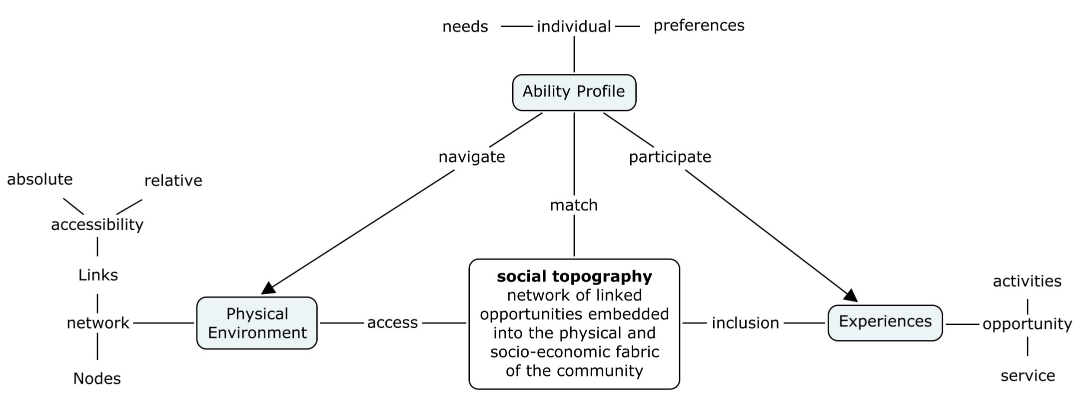


Figure 3.1 Social topography framework.

The underlying foundation of social topography rests on the structural dynamics of physically and socially negotiated networks. Network theory is used here because, unlike traditional statistical analysis, this approach focuses on interdependency of variables

(Wasserman & Faust, 1994). The nodes and edges that define a network (based on Graph Theory) parallel the features and transport networks that constitute the real world.

Frank and Engelke (2001) believe that the network approach, while the most precise, is too expensive to utilize. However, because of advancements in technologies like geographical positioning and information systems, geo-spatial network analysis, smart cities, mobile technologies and approaches such as micro-simulation modeling, agent based modeling, crowdsourcing and virtual environments, costs have decreased. The advent of computational social sciences opens up possibilities generally considered unwieldy previously. Because people who use mobility devices have great sensitivity to the connectedness of the environment, a network approach is the only accurate choice. The more detail we can add to our understanding of our social topographies, the better our chances are of designing, developing and managing environments that serve everyone.

In the example below (see Figure 3.2), the network may be considered dense but because of a critical link between a person's home and the final destination is not accessible - the rest of the network becomes unreachable. Traditional approaches would deem this a walkable neighbourhood but this is clearly not the case for someone who can't overcome that first link in the chain.

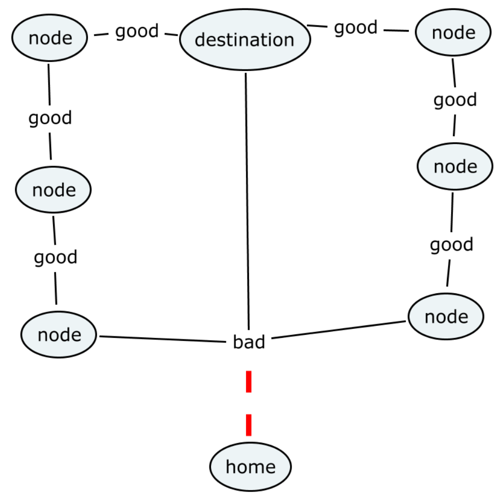


Figure 3.2 Dense but unreachable network.

3.3 Structure

At its most basic, social topography is a network of linked nodes. These nodes and links have objective physical and socioeconomic qualities that can be measured (see Figure 3.3 Social topography model.). Nodes offer opportunities and are helped or hindered by their physical attributes as well as the policies and practices that define their inclusiveness. Links are the paths and transport modes that connect nodes. They have attributes that essentially act as burdens for getting from one node to the next (note: this isn't necessarily negative from the perspective of a recreational pursuit). The networks that emerge from these connections (and their deletions) define the parameters for a given physical location. Comparing the Ability Profiles of PWDs against the environmental constraints sheds light on the accessibility and inclusion for each population.

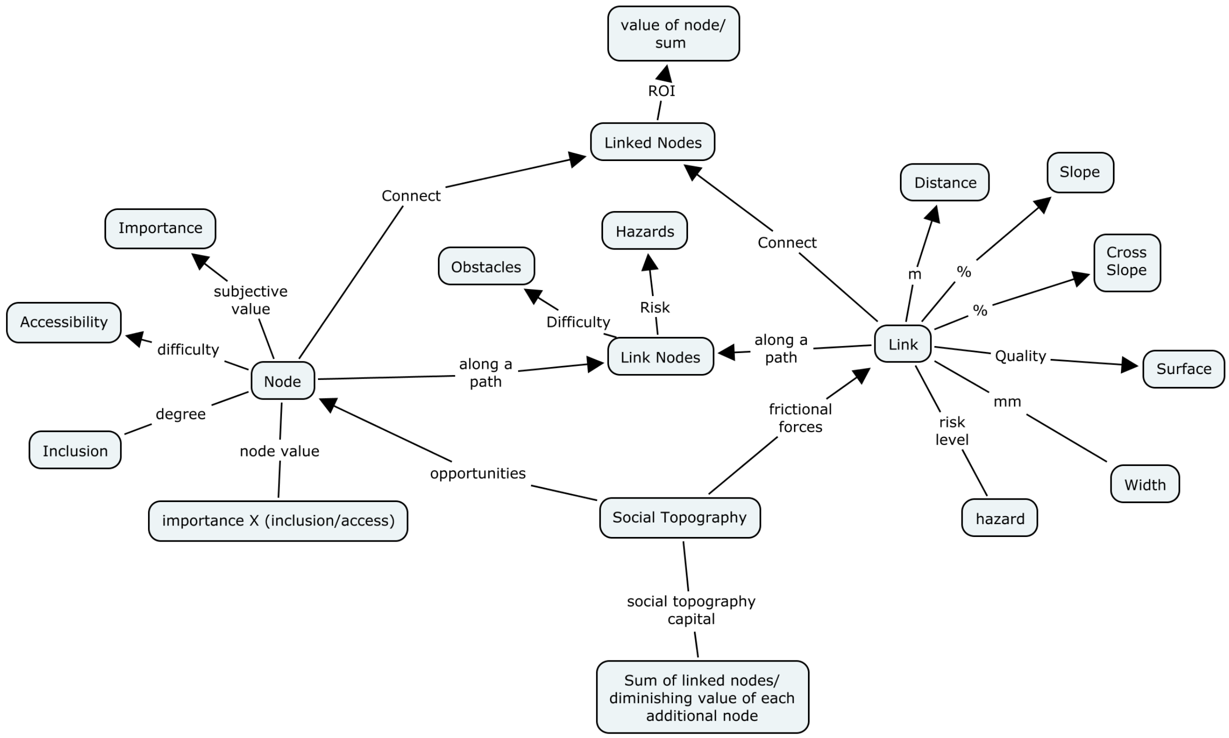


Figure 3.3 Social topography model.

3.3.1 Nodes

In the social topography model, nodes represent features (e.g. public washroom), or places (e.g. an aggregate of features like a restaurant) at a defined geographical location that offer opportunities and experiences (e.g. dining). Nodes can be grouped into classes (e.g. dining, shopping, recreation) and subclasses (e.g. cafés, ice rinks, and fruit stands) based on the functions and experiences they provide. These classifications can be used in the final analysis to determine if a full range of opportunities exists in a community. For example, a region might want to ensure an adequate variety of outdoor recreation opportunities available.

a) Features and amenities

At the smallest scale, a node is a feature or amenity such as a shop or park bench. A feature refers to nodes that are the primary components of places that draw people to them. People go to restaurants to dine. The washroom is a secondary amenity that complements the primary experience. This difference is somewhat subjective but does not impact the analysis significantly. Features have physical attributes that are measurable and impact functional access (e.g. a restaurant with only booths and fixed seating may limit someone in a wheelchair) and informational attributes like who is responsible for managing that feature (e.g. local municipality maintains public water fountains). Features and amenities include built and natural components like piers, benches, public washrooms, scenic viewpoints, playgrounds, and hotel suites. Features are tangible and thus have geographical coordinates (i.e., latitude, longitude, and elevation) as well as temporal aspects (e.g. a weekly farmers market, annual festival, seasonal access, etc.).

Typically, features come together in one place (e.g. a park or restaurant) to offer a defined set of opportunities (e.g. recreation or dining). For instance, a restaurant is made up of features like an entrance, dining area and washroom. The entrance width, table heights, and clear space in the washroom are some of the physical attributes that can be measured. Collectively, these features constitute a place. In some cases, places come together to share resources (e.g. amenities and services) within a single space. A mall, as an example, is a group of businesses that share a common parking lot, main entrance, and public washroom facility. A park is another example of a space. Spaces are mini-networks that can be condensed into a single node for use at larger scales. This illustrates the value that a scale free model offers urban analysts and policy makers.

b) Measurable attributes

The functionality of a feature is based on the measure of its attributes. An entrance is composed of attributes like clear space measured by the length and width of the level space in front of it. The door also has attributes like door width, threshold height, and lighting intensity measured in lumens. These attributes and their measures may change over time due to season/weather or on how they are managed and operated. In nice weather, a double door may be left open but once the weather turns, one door is locked and the other is closed. The result is a change in the functional measure of the attribute(s). These measures are discussed further in the data collection section.

c) Services and Programs

The service or experience provided by a place is impacted by policies and practices that the organizations that manage them have in place. The level of inclusion ($\acute{\iota}$) will be determined by the degree to which everyone can participate in the experience. Not every node, however, is of equal value. The importance (Φ) subjectively assigned to a node or class of nodes will impact the final analysis. For instance, a hospital is likely to be considered far more important than a jewelry store. This can be noted by assigning different levels of importance to different types of nodes. This hierarchy of nodes is spread out throughout a community and is connected to a lattice of transportation options.

3.3.2 Links

Nodes are linked together over a measured distance by paths, trails, and sidewalks with attributes (also referred to as path conditions or frictional factors) like slope (i.e., grade or running slope), cross slope (slope perpendicular to the path of travel), surface conditions, width, and presence of hazards. Distance (d) and width (w) are measured in metres, slope (s) and cross slope (c) in percent, surface (u) is characterized as being stable, firm, even, and slip resistant, and hazards (h) resulting from local safety and security risk (e.g., car traffic, pedestrian traffic, crime, etc.). A stable surface remains unchanged by applied force so that when the force is removed, the surface returns to its original condition. Pea gravel is usually firm (won't sink) but may move side to side as contact begins and ends. A firm surface will reduce how much an individual will sink as they move down a path. Concrete, pavement, and boardwalks are examples of very firm surfaces. Surfaces that are smooth and even reduce the chance of stumbling. Surfaces with materials of higher gauges are likely to cause people to stumble. Slick surfaces or surfaces with loose materials on top are often slippery. Additional conditions like aesthetics, safety, and security can also be applied to links.

Similar to nodes, not all path conditions have the same degree of impact and this can be subjectively adjusted by assigning a relative factor (r) to each one. For instance, running slope (s) has a greater impact on the effort required to travel down a path than the width of that path. The same is true of cross slope but to a lesser degree. The relative factors assigned may be different for different Ability Profiles or even customized for a single individual. That being said, values used in this study are derived from existing standards, academic research, and 25 years of experience traveling with a manual wheelchair.

3.3.3 Link Nodes (Connectors)

In the social topography model, there are special nodes deemed link nodes because they are directly tied to a path of travel but do not offer intrinsic value. These can be obstacles like obstructions, hazards, curb cuts, elevators, ramps, and stairs that impede travel. Link nodes can also be wayfinding and signage that help navigation or simply markers that denote a change in path conditions or an intersection/path terminus. These nodes are evaluated by the frictional challenge they may present to the traveler. Hazards take the form of crime, traffic speeds, pedestrian traffic, uncontrolled crosswalks, overhead hazards, protruding hazards and ground hazards. The amount of risk produced by a hazard depends on the nature of the hazard and its context and is therefore less reliable of a measure. These nodes have measurable attributes similar to features and amenities.

3.3.4 Networks

Nodes that are linked together are called networks. Networks have compositional attributes (e.g., number of cafés within 200m) and structural attributes (e.g. robust networks require the removal of more links before they become disconnected). As nodes connect to each other (i.e, dyads to triads, etc.), complex structures emerge that are difficult for urban planners and pedestrians to process. Using visualization tools and advanced algorithms, these patterns can be made understandable to the end user (Wasserman & Faust, 1994).

Networks can be decomposed into smaller networks based on rules about how someone negotiates them. This will be helpful when trying to analyze the effectiveness of AMNs. From the network analysis field, the following definitions describe specific network components that mimic how people interact with their environments:

- A walk is a series of connected nodes with a length that is a sum of the link values between them. Walks can start and end at different points, allowing for repeated nodes and lines.
  - A closed walk starts and ends at the same node and can have direction
  - A trail is a walk where every link is distinct but nodes can be repeated
  - A cycle is a trail that starts and ends at the same node
  - A network or sub-network that has no cycles (acyclic) is called a tree
  - A disconnected network with a lot of trees is called a forest
  - A tour is a cycle that uses every link in the network
  - A path is a walk where every link and node is distinct
  - A geodesic is the shortest (or least burden) path between 2 nodes
  - The diameter of a network is the largest geodesic in the network
  - A Hamiltonian trail is a cycle that uses every node and link in the network

(Wasserman & Faust, 1994)

3.4 Analysis

Analysis requires defining the Ability Profiles of the user groups to be compared and the analytical measures to be used. The values and formulae developed are a product of three sources: 1) significant personal and professional experience in this area of the author (25 years with a mobility impairment, 20+ years of working with others with a range of disabilities; 10 years of experience helping to assess accessibility); 2) the research already cited; and 3) network analytics to be discussed in this section. Most of the analysis that follows concentrates on evaluating paths and obstacles that exist along those paths.

3.4.1 Measuring Access and Inclusion

Because attribute measures have different units, there needs to be a way of comparing them. Accessibility, denoted by (a) is scored as being easy (value = 1), moderate (2), difficult

(3), or very difficult (4) based on a range of values for each attribute measured. Existing standards found in access standards (like Canadian Standards Association and Americans with a Disability Act standards) are used to calibrate the system by representing the moderate access scores for attributes. From this, the other value ranges are determined. For example, path slopes in the real world usually range from about 0 to 15%. Slopes in the range of 0 to 2% are easy and scored a 1. Slopes 2 to 5% are of moderate difficulty and scored a 2. Slopes 5 to 8.3% are difficult (scored a 3), and anything steeper is scored a 4. These are just initial values and need to be studied further.

Nodes, links, and link nodes are measured using a series of checklists consisting of attributes with ranges of measures. The final value assigned to a feature is defined by its most restrictive attribute. A door might be very wide, easy to open, but have a 25cm threshold and would therefore be scored a 4 for access.

Inclusion, not addressed in this work, is the degree to which any individual may participate in an activity as a result of policies and practices. For instance, many floatplane services have a policy that they will only allow people who can independently board and leave the plane from flying with them. This policy is an absolute barrier on participation and would deter someone who is a complete paraplegic from participation. Other, less explicit practices, like not offering adapted programs or equipment deter participation even without policy. There is a range of inclusiveness that can be measured that includes communications, training, and more.

This scoring system is just a starting point for the analysis and needs to be adjusted in future research. This may include defining the range of values, scoring, and weighting of the relative factors assigned to path conditions. This is meant to be flexible as these values are dependent on the abilities of the individuals in question. Comparing scoring and weighting systems against the perceived experience of individuals in real world situations is the most useful way of recalibrating the measures.

3.4.2 Ability Profiles of Model Users

Ability Profiles for able-bodied people, paraplegics using manual wheelchairs, quadriplegics using manual wheelchairs, and scooter users are proposed below (see Table 3.1). The columns represent the environmental constraints and each role provides the attribute measures that would be attributed to the four levels of difficulty being proposed. Each path condition is scored on a 1 (easy) to 4 (very difficult scale). This will be used in the data analysis.

Table 3.1 Proposed APs for analysis.

	Able-bodied	Paraplegic	Quadriplegic	Scooter
Slope				
Easy	0 – 5%	0 – 2%	0%	0 - 5%
Moderate	5.1 – 8.2%	2.1 – 5%	0.1 – 2%	5.1 – 8.3%
Difficult	8.3 - 12%	5.1 – 8.3%	2.1 - 5%	8.4 - 10%
Very Difficult	> 12%	> 8.3%	> 5%	> 10%
Cross Slope				
Easy	0 - 5%	0 - 1%	0%	0 - 2%
Moderate	5.1 – 8%	1.1 – 2%	0.1 – 1%	2.1 – 3%
Difficult	8.1 – 10%	2.1 -5%	1.1 – 2%	3.1 – 4%
Very Difficult	> 10%	> 5%	> 2%	> 4%

	Able-bodied	Paraplegic	Quadriplegic	Scooter
Surface*				
Easy	0 – 6pts	0 – 2pts	0 – 1pts	0 – 4pts
Moderate	7 – 9pts	3 – 4pts	1 – 2pts	5 -6pts
Difficult	10 – 11pts	5 – 9pts	3 – 6pts	7 – 8pts
Very Difficult	12pts	10 – 12pts	7 – 12pts	9 – 12pts
Width				
Easy	> 810mm	> 1.5m	> 1.5m	> 2m
Moderate	751 – 810mm	921 – 1500mm	921 – 1500mm	1.51 -2m
Difficult	500 – 750mm	810 – 920mm	810 – 920mm	1.21 – 1.5m
Very Difficult	< 500mm	< 810mm	< 810mm	< 1.2m
Obstacles				
Easy	< 25mm	<7mm	none	< 7mm
Moderate	25 – 50mm	7 – 13mm	0.1 – 7mm	7 – 13mm
Difficult	51 – 180mm	13.1 – 25mm	7.1 – 13mm	13.1 – 25mm
Very Difficult	> 180mm	> 25mm	> 13mm	> 25mm

Points for surface are awarded based on the intensity (none, moderate, significant) of 3 characteristics. To determine a surface's level of difficulty, values are summed from the three categories below:

- Slip and slide (none = 0pts, moderate = 5pts, significant = 9pts)
- Sink (0, 3, 5)
- Stumble (0, 3, 9)

Slipping and sliding is a measure of the horizontal stability of a surface. This may be caused by surface material that is very slick (e.g. porcelain tiles) or a surface covered by materials that move side-to-side easily (e.g. leaves, small rocks). Surfaces that sink are soft and provide greater resistance to someone wheeling on them (e.g. wet grass). Lastly, surfaces that cause people to stumble are often uneven (e.g. tree roots underneath pavement or high gauge rocks) or have seams (e.g. a gap in a joint between two different surface types). These surfaces will easily stop the front casters (two small wheels at the front of most manual wheelchairs). The degree to which a surface is slippery, sinks, and is uneven is either moderate or significant (a subjective evaluation). The width of a surface is measured across an uninterrupted path including protruding obstacles as well as ground conditions (e.g. if there is a joint between to surfaces, this represents its edge).

3.4.3 Evaluating Nodes

A feature node (Θ^*) is evaluated based on the inclusiveness (*i*) of its intended purpose(s) and the accessibility (*a*) of its physical structures. Because not all nodes are of equal importance, a subjective importance factor (Φ) is introduced.

$$\Theta^F = \left(\frac{\Phi}{a}\right)$$

Figure 3.4 Value of a feature.

$$\Theta^P = \Phi * \left(\frac{i}{a}\right)$$

Figure 3.5 Value of a place.

The formulae above evaluate the value derived from a feature. To arrive at a utility value (see Figure 3.4), divide the subjective value of a node of that type by the access score calculated during the assessment (see previous discussion). Nodes like benches, water fountains and other amenities utilize this formula. Places, on the other hand, provide a service and require an assessment of the breadth and depth of the inclusiveness of their service or opportunity. Places like restaurants, hotels, and recreation centres refer to the second formula (see Figure 3.5). In this equation, the utility provided by the place is calculated by dividing the inclusion score by the access score determined during the assessment. This result is then multiplied by the subjective importance value for a place of that kind. In the case studies being performed, features will not be assessed but it is important to see how all the elements are evaluated.

3.4.4 Evaluating Links

Arentze et al. (1994) suggest evaluating links by assessing travel costs (time or distance) representing the ease of reaching a destination), opportunities at destination in light of travel costs, utility functions (benefits and costs). Links create a demand on the user – one of absolute access ($|\boldsymbol{a}|$) and the other relative access or burden (β). An absolute access demand is a barrier that effectively removes the link from an individual's social topography whereas relative access places an increasing burden on the individual. All individuals have limits on the burden (available physical, social or economic capacity) they are willing to manage. Pedestrian path accessibility is a product of path conditions (π); slope, cross slope, surfacing, width, and presence of hazards and obstacles. The burden of that path then is the product of those path conditions over a defined distance.

A link segment (π) is a continuous path that is defined as having conditions that do not change over a measured distance (d). Attributes (i.e., path conditions) include slope (*s*), cross slope (*c*), surface (*s*), width (*w*), and hazard risk (*h*). The value for each attribute is based on a range of values between 1, being the least restrictive and 4, being the most restrictive. Not all path conditions have the same degree of impact so a modifier r_x is introduced to weight them accordingly. The frictional load (i.e. impedance factor) of a link is the product of the weighted factors over a specified distance (see Figure 3.6).

$$\pi = \frac{d}{100} * \frac{r_s s + r_c c + r_u u + r_w w + r_h h}{\sum r_x}$$

Figure 3.6 Frictional load of a link.

Modifiers are subjectively assigned and may be different for one population or even individual. Generic values that approximate the impact people with disabilities are: slope = 5, cross slope = 3, surfacing = 5, width = 1, and hazard=1.

Example: If all accessibility values were scored as 1s except slope being scored a 4 over a 400m-path segment, the absolute access would be 4 (based on the most limiting condition along the path segment). However, the relative access would be (30/15 * 4 = 8).

$$\pi = \frac{400}{100} * \frac{(5 * 4) + (3 * 1) + (5 * 1) + (1 * 1) + (1 * 1)}{15}$$

The burden (β) of the path is the sum of all the accessibility scores for each path segment plus the sum of all the accessibility scores for any obstacles (*b*) or hazards (*h*) (see Figure 3.7). Obstacles and hazards are modified based on their differential impacts on path of travel. A barrier or hazard may pose an absolute barrier if it is outside defined parameters.

$$\boldsymbol{\beta} = \sum(\boldsymbol{\pi} + \left(\frac{\boldsymbol{b}}{\mathbf{8}}\right) + \left(\frac{\boldsymbol{h}}{\mathbf{12}}\right))$$

Figure 3.7 Burden of an entire trail.

This formula is relied upon heavily in the research because most of the phenomena measured are obstacles (e.g. cross walks, driveway crossing, and obstacles).

3.4.5 Evaluating Networks

Evaluating networks or sub-networks starts to become more complicated. In its simplest form, a network can be represented as a dyad (two nodes connected by a link). Linear paths, like the ones being studied here, are examples of simple networks. The value of this connection is a product of the value of the node divided by the burden of reaching that node (see Figure 3.8). This is, in essence, a formula for the return on investment.

$$\Omega = \frac{\Theta^*}{\sum \beta}$$

Figure 3.8 Value of single linked node

A far more complicated calculation is to consider the value of all the nodes (i.e., the social topography capital) in a network (see Figure 3.9). One approach is to sum the value of all the possible destinations from a single origin. Because adding more and more of the same thing offers diminishing return, a modifier is introduced that reduces the value of adding another destination in that category. For example, adding more coffee shops into a neighbourhood will only be of marginal value. Each coffee shop can be ranked (rank) based on their value and diminished by an exponent (dim). The exponent can be subjectively set to reflect the importance of adding additional features of the same class (e.g. coffee shop). To adjust the impact additional features or places have on the overall value of the network, a higher the exponent can be used. For instance if a diminishing factor of 2 is used, then the value of the second coffee shop will be reduced by 1/4th and the third instance will be reduced by 1/9th. When the exponent is set to 2, the denominator will increase by the square of the rank. If a diminishing factor of 3 were chosen, the denominator would increase by the cube of the rank, etc.

$$\alpha = \sum\left(\frac{\Omega}{rank^{dim}}\right)$$

Figure 3.9 Social topography capital.

The focus of this thesis will be on examining the properties of paths and their ability to connect nodes in the network. The results of the audits will be used to qualitatively and quantitatively assess absolute and relative accessibility measures. Absolute accessibility will be compared by setting maximum accessibility score and applying this to each path to see how it impacts the results. A similar approach will be used for relative accessibility by setting a maximum burden on each path and evaluating results.

Because of the nature of the case studies, more robust network measures are not possible but the simple measures make this possible. Insights into how this might come about will be addressed in the analysis and discussion.

3.5 Dynamics

The view of social topography structure described above provides a snapshot of a much more dynamic system. It is the interaction between the individual and the physical and socio-economic environment that embodies the realities of people's lives. A simple model is described below to depict social topography in action.

The seamless experience life cycle (see Figure 3.10) is a simple model to describe how citizens experience their communities. Brohman et al. (2009) describe the interaction between the individual and the experience as the opportunity for value creation. Success is derived from fostering an environment where the end user is a co-creator of the experience. In the community context, the experience life cycle is continually informing the decisions people make. While the model is ideally describing a structured community experience like choosing a restaurant or signing up for a recreation program, it is applicable to less structured activities like taking a walk or going to the park.

Figure 3.10 Seamless Experience Life Cycle

At the edge of the circle is the interface between person and environment. It is the point at which someone's needs and preferences intermingle with environmental constraints and opportunities. On the inside of the circle are the activities that organizations do to make an opportunity available to the public (e.g. staff are trained to help people onto a roller coaster or a policy prohibits people under a certain height from riding that roller coaster). The process describes 5 stages of an experience, what the organization does, and what the expectations of the public, referred to as the end user in this description, are. Each stage, and the handoffs between stages, places a challenge on the end user to be able to participate. Accessibility and inclusion are key challenges throughout.

The discovery phase is about raising awareness about the opportunity. Through various communication channels, the potential market begins to learn more about the opportunity so that they can decide whether this is something they want to participate in. The message and format of the content is very important at this stage as expectations are starting to be developed. PWDs need to know if the parameters (physical and social) of the experience meet their needs and preferences. Organizations can establish a relationship of trust with their target audience by providing accurate and complete information at this stage.

Once a decision is made to participate, guides (e.g. maps to the location, reservation systems, etc.) will help them arrive at the location. For defined programs and services, frontline staff is responsible for the delivery of the experience (in collaboration with the end user). After the experience is over, end users evaluate the opportunity to determine if they might do it again or even recommend it to others (i.e. customer loyalty).

These five stages are continuous cycles of opportunity for the organization and end user to continually improve the experience (Gentile et al., 2007). When serving PWDs, the challenge is to create a seamless physical and socio-economic experience within and across stages. This goal is accomplished by understanding the needs and preferences of this heterogeneous group.

3.6 Case Study Approach

In order to describe and contrast the impacts the measures of certain features and conditions have on the levels of access connecting two features in a neighbourhood network, accessibility audits will be conducted using an audit tool on a smart phone. The tool (see Appendix C) uses a set of checklists to assess and compare the accessibility of paths and features. Audits of the paths (sampling unit) that connect transit hubs to key community resources and residences in the Lower Mainland of British Columbia are conducted. A qualitative and quantitative analysis of the paths audited are analyzed and compared across Ability Profiles.

A purposive sample of paths have been chosen to attempt to show the impacts that extreme measures of common attributes of paths can have on distorting the accessibility of a neighbourhood. The sample consists of 3 transit hubs (origins) and 3 community resources and residential locations (destinations) within approximately 200 to 800m of the hub (straight-line distance). This distance range is commonly used in the field of urban planning to represent reasonable walking distances for the average person. This is a non-probability targeted sampling technique. The samples are intended to offer insights into attributes that differentiate accessibility, not a general description of accessibility in those communities.

According to Yin (1989), a case study is a research method that focuses on specific phenomenon within a practical application. Gerring (2004) warns, however, that this is not a way to model cause and effect. The case studies proposed in this thesis focus on path accessibility around transit stations. It will illuminate misconceptions about how to think about accessibility in real world applications. This approach identifies accessibility attributes and metrics within a bounded system.

Creswell (2009) describes this as a proper use of the case study methodology although misconceptions about the value of case studies abound. Flyvbjerg (2006) reminds us that case study research can yield important information; generalizations can be made from a case study; hypotheses can be tested; bias is not inherent; and, case studies can be summarized succinctly.

In an effort to quantify these environments more, Sakkas & Perez (2006) used a network analysis approach to examine circulation patterns and quality. They build on previous work by differentiating between absolute (barriers) and relative accessibility (e.g., longer routes to get from one point to the next). The authors describe 5 measures of accessibility in a bounded region– counting the number of opportunities in it, total sums of travel distance to all opportunities, proximity of opportunities, potential opportunities, and probability of utilization. These measures can be adapted to fit a model of active transportation for everyone. This research begins to bridge the research gap by scaling down to the pedestrian perspective. Church and Marston (2003) use a similar approach in their research.

3.7 Case Study Selection

Three major transportation stations (SkyTrain) in the Lower Mainland serve as the central points for the three case studies that follow (see Figure 3.11). Vancouver Broadway City Hall, Richmond Brighouse, and Surrey City Centre were chosen as cites because they are key nodes in the transportation networks for their municipalities. The neighbourhoods that surround these stations are relatively dense and have mixed land uses. They are dense residential and employment centres that draw thousands of people to and from them each day. All stations are within walking distance (< 800m by foot) of their city halls as well. Many of the principles discussed in the theoretical section are embodied in the immediate vicinity. Walk Scores (an algorithm developed with a grant from the Robert Woods Johnson Foundation and advised by Dr. Lawrence Frank in 2011) are calculated to illuminate the compositional view of walkability (i.e., density of opportunities around a single point).

Figure 3.11 Case study areas.

From each transit station, 3 target destinations have been chosen. The destinations chosen represent resources in the community that are visited regularly or are from a defined residence (home or apartment complex). An attempt to cover a representative amount of the area was done by choosing destinations towards the edges of the area in all directions. Between each station and targeted destination, three direct paths are identified. The purpose of choosing three is to explore whether or not arriving at the destination could be significantly impacted by a disruption in service (e.g. weather conditions or construction) that would make the path unavailable.

Each path will be assessed for:

- Distance
- Slope
- Cross slope
- Surface quality (firm, stable, non-slip)
- Width
- Presence of obstacles
- Presence of hazards

3.7.1 Vancouver Broadway – City Hall

The Vancouver Broadway – City Hall SkyTrain station entrance is at the southeast corner of Broadway and Cambie Street in Vancouver, BC. It is at a plateau along the rise from False Creek in the north (downhill) towards the Cambie Street Bridge and to the south (uphill) towards Vancouver City Hall and City Square Centre Mall. The Broadway corridor that runs east to west is one of the busiest transportation corridors in Vancouver not serviced by a SkyTrain route. A great deal of this traffic is staff and students heading west towards the University of British Columbia and east towards Simon Fraser. It is a transfer point to this traffic and those going through the Cambie corridor. The Cambie Street Bridge is a busy car, pedestrian and bike bridge.

The three destinations chosen are:

- Vancouver General Hospital (see Fig 3.12 and Table 3.2)
- Vancouver City Hall (see Fig 3.13 and Table 3.3)
- Apartment complex on Millyard (see Fig 3.14 and Table 3.4)

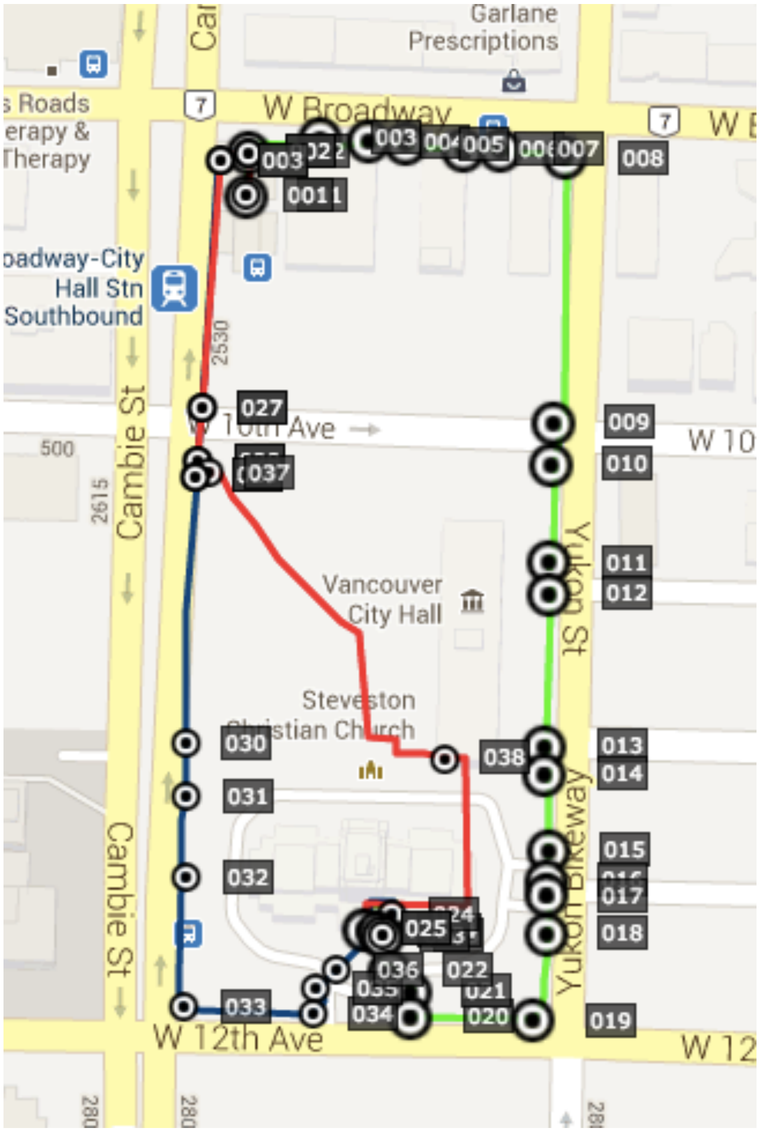


Figure 3.12 Vancouver City Hall paths

Table 3.2 City Hall Path routes

271m straight-line distance Walk Score= 95		
Route #	Network Distance (m)	Route
1	517	East on Broadway, South on Yukon, West on 12th Ave
2	397	South on Cambie, through park, back entrance, through corridors to front entrance
3	504	East on Broadway, south on Yukon, west on 12th, front entrance

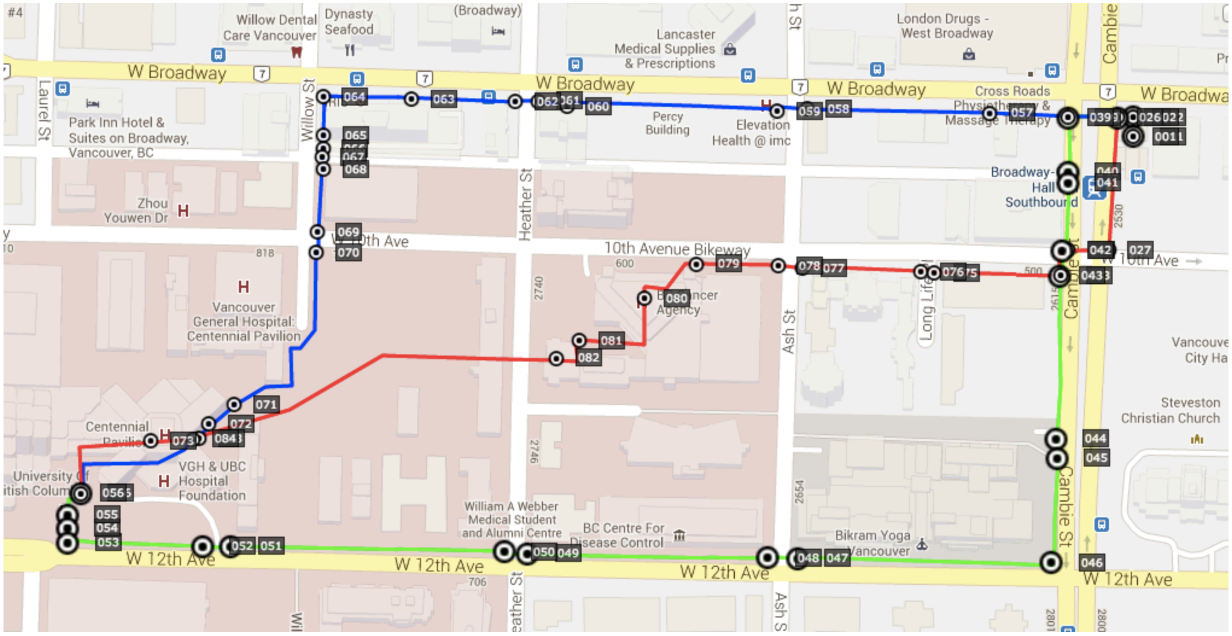


Figure 3.13 Vancouver Hospital Paths

Table 3.3 Vancouver Hospital routes

712m straight-line distance Walk Score = 92		
Route #	Network Distance (m)	Route
1	1008	South on Cambie, west on 12th, front entrance
2	899	West on Broadway, south on Willow, through park back entrance, through corridor, front entrance
3	810	South on Cambie, west on 10th, in BCCA, through corridors and tunnel, back entrance, corridors to front entrance

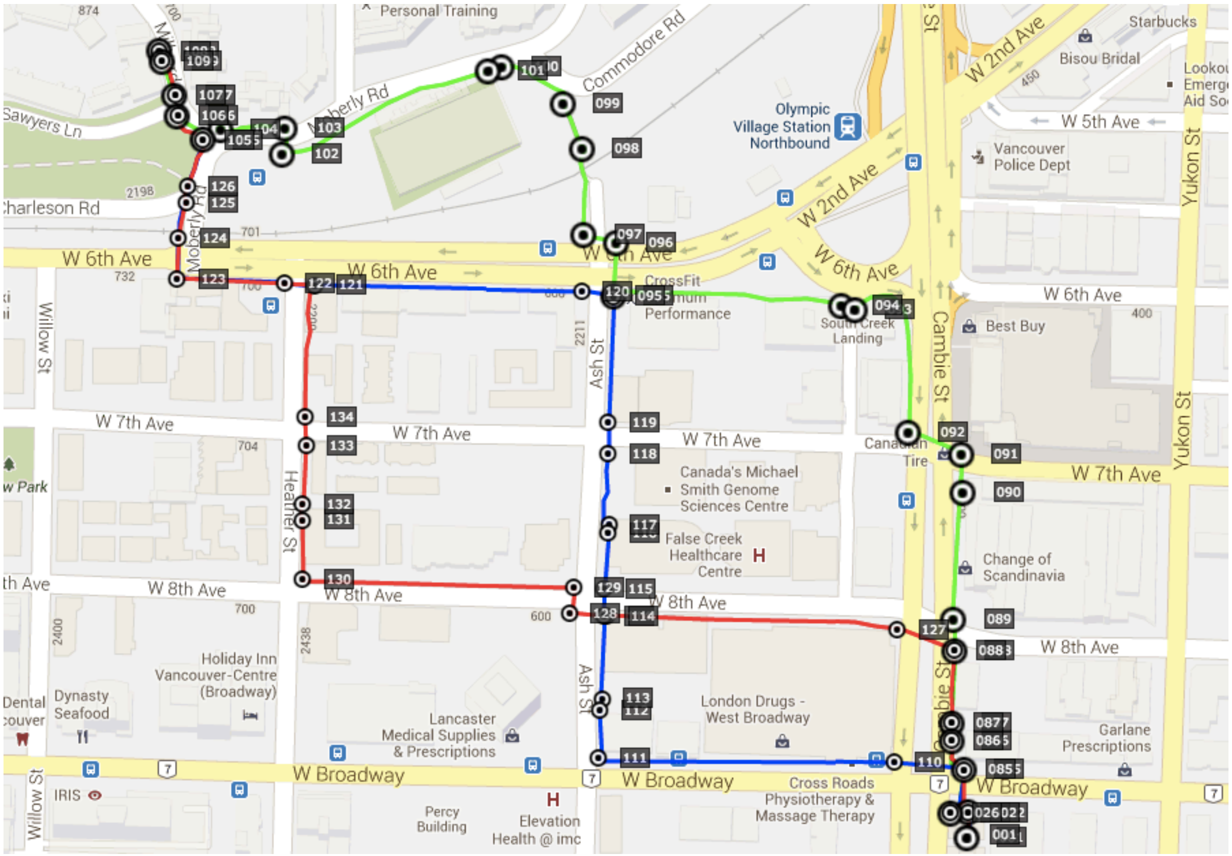


Figure 3.14 Millyard paths

Table 3.4 Millyard routes

716m straight-line distance Walk Score = 87		
Route #	Network Distance (m)	Route
1	963	North on Cambie, west on 6th, through trail, north on Moberley, right on Millyard,
2	944	West on Broadway, north on Ash, west on 6th, north on Moberley, right on Millyard
3	949	North on Cambie, west on 8th, north on Heather, west on 6th, north on Moberley, right on Millyard

3.7.2 Surrey City Centre

Surrey City Centre station is a recently revitalized neighbourhood with billions of dollars of investment going into it. It is surrounded by a mature neighbourhood to the east and west and has mixed use in the core. Much of the work has been done but it is not complete (e.g. the new City Hall opens in February 2014). A major shopping mall and the Simon Fraser University satellite campus are across the street from the recreation centre. There is a high density of employment and residential uses close by. The destinations chosen for this cite are:

- Residence on 99A Ave (see Fig 3.15 and Table 3.5)
- Kwantlen Park Secondary School (see Fig 3.16 and Table 3.6)
- Fitness Centre (see Fig 3.17 and Table 3.7)

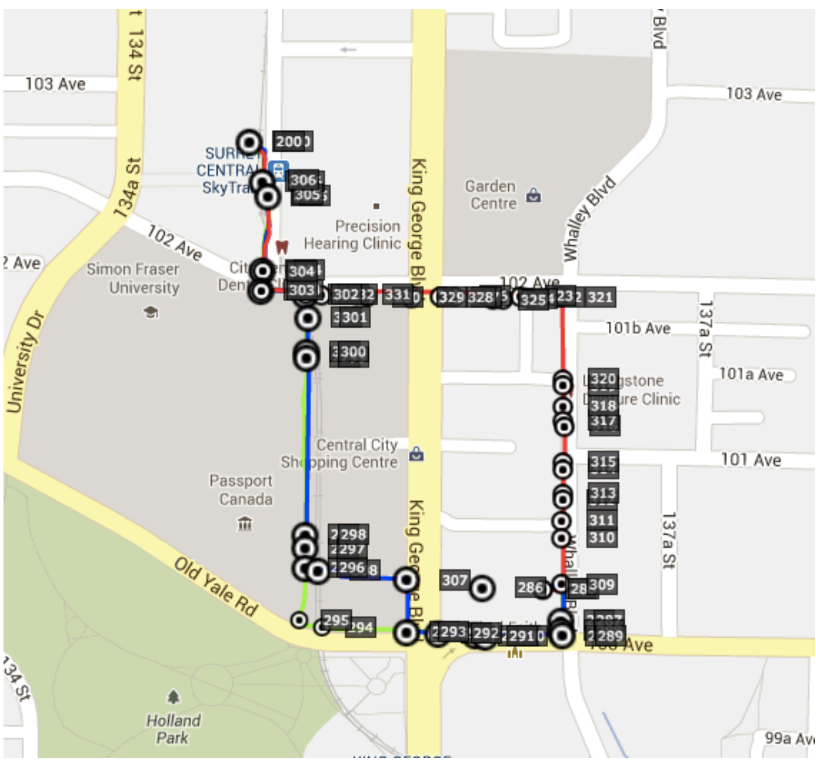


Figure 3.15 Fitness Centre paths

Table 3.5 Fitness Centre routes

575m straight-line distance Walk Score=87		
Route #	Network Distance (m)	Route
1	950	south on City Parkway, east on Old Yale, north on Whalley
2	943	south on City Parkway, across City Parkway, through parking lot, south King George, east on Old Yale, north on Whalley
3	856	north on Whalley, west on 102, north on City Parkway

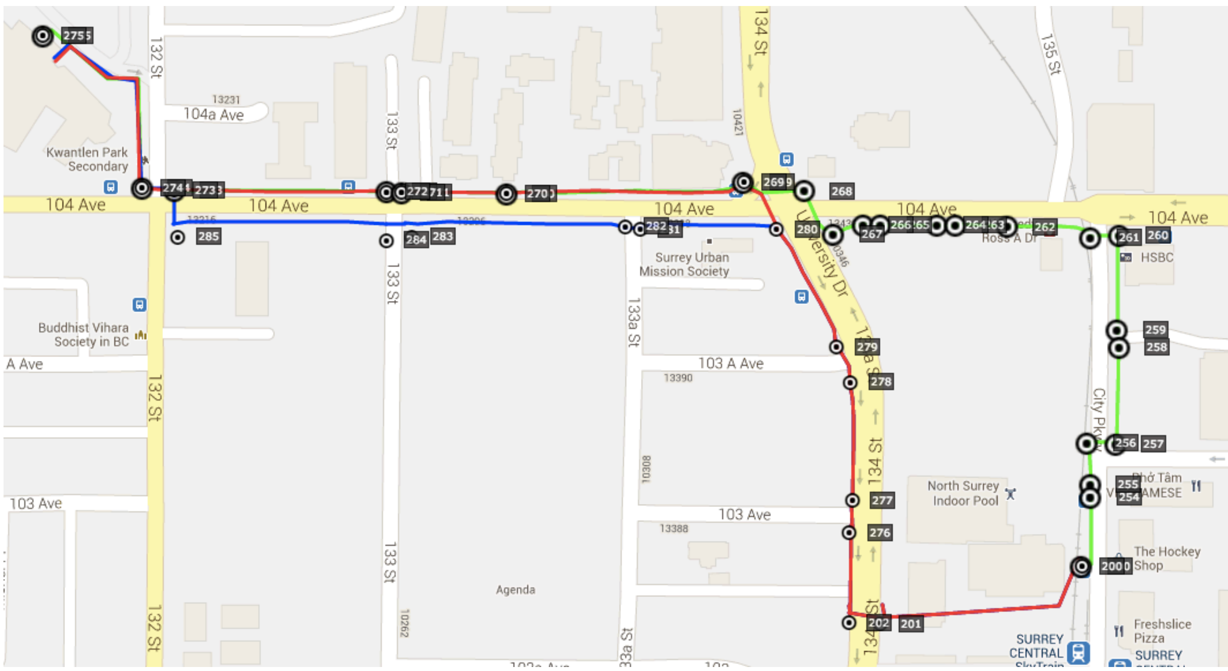


Figure 3.16 Kwantlen Park paths

Table 3.6 Kwantlen Park routes

790m straight-line distance Walk Score = 75		
Route #	Network Distance (m)	Route
1	1016	north on City Parkway, west on 104 , north on 132
2	1036	west through Rec Centre, west on 103, north on 134, west on 104, north on 132
3	1342	north on City Parkway, west on 104, north on 132

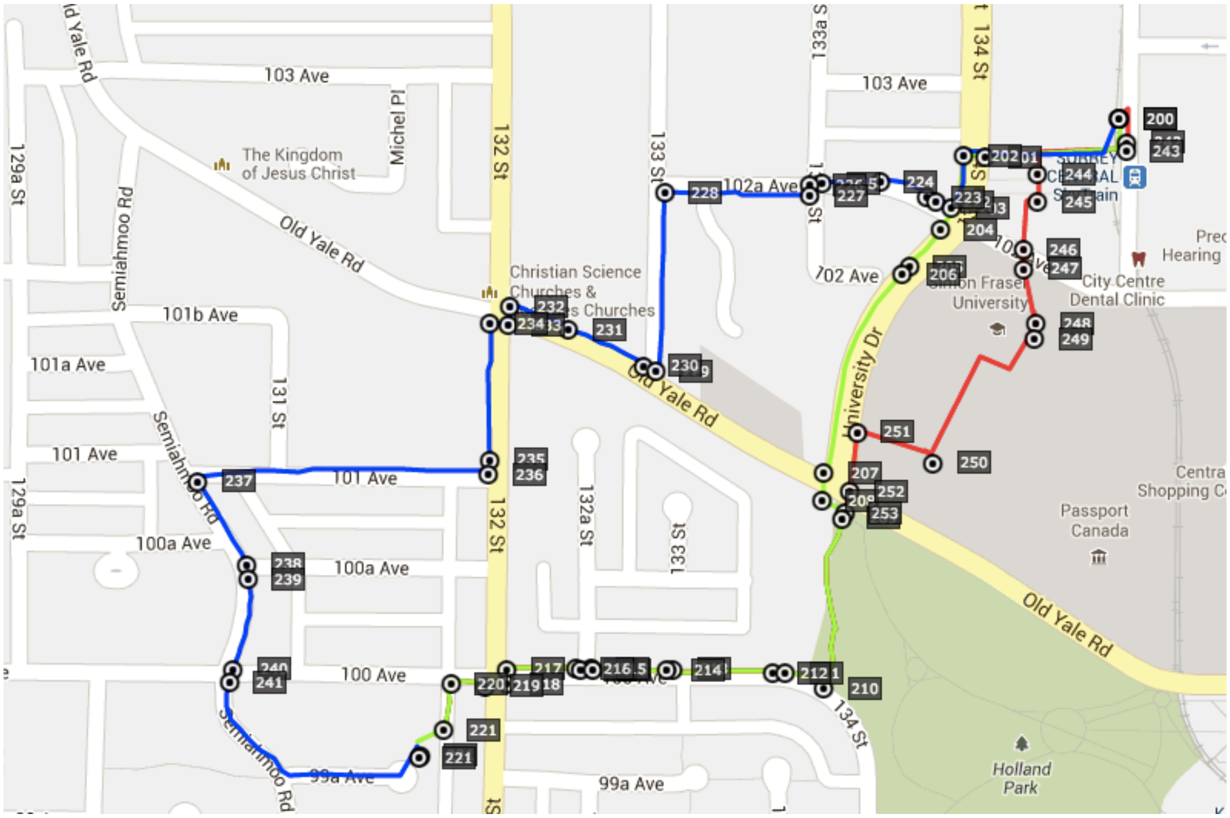


Figure 3.17 99A residence paths

Table 3.7 99A Avenue residence routes

830m straight-line distance Walk Score = 67		
Route #	Network Distance (m)	Route
1	1620	west to University, south on University, through park, west on 100, south on Semiahmoo, east on 99A
2	1836	west to University, south on University, west on 102A, south on 133, west on Old Yale, south on 132, west on 101, south on Semiahmoo, east on 99A
3	1196	southwest to 102, south through mall, west to University, south through park to 100, west to alley, south to rear entrance

3.7.3 Richmond Brighouse

The Richmond Brighouse SkyTrain station is the southern terminus of the new Canada Line that goes north to downtown Vancouver with a spur to Vancouver International Airport

(YVR). It is across the No. 3 Road from the Richmond Centre Mall and three blocks from Richmond City Hall. No. 3 Road is Richmond's busiest automobile corridor. The surrounding neighbourhood is a major employment centre. Condominium developments sprouted up near the station, complementing a number of existing residential towers. Beside City Hall is the Brighouse library and museum. The destinations chosen for this site are:

- Richmond City Hall (see Figure 3.18 and Table 3.8)
- Richmond Hospital (see Figure 3.19 and Table 3.9)
- Richmond Market (see Figure 3.20 and Table 3.10)

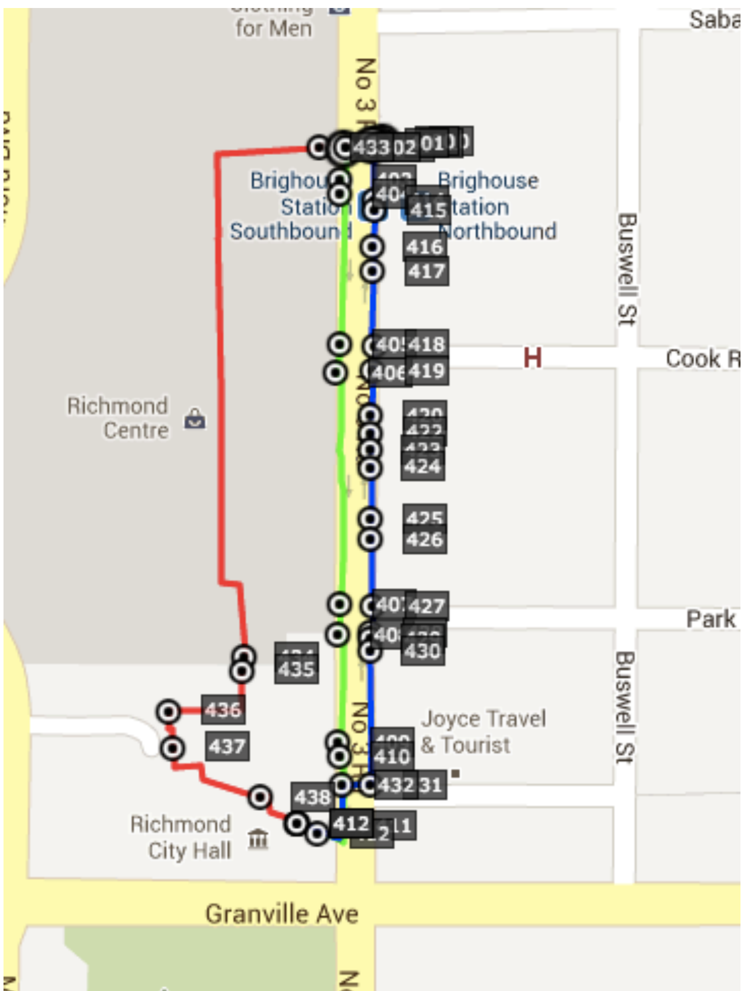


Figure 3.18 Richmond City Hall paths

Table 3.8 Richmond City Hall routes

551 m straight-line distance Walk Score = 100		
Route #	Network Distance (m)	Route
1	591	south on No. 3 west side, entrance
2	606	south on No. 3 east side, entrance
3	761`	west through mall, back entrance, entrance

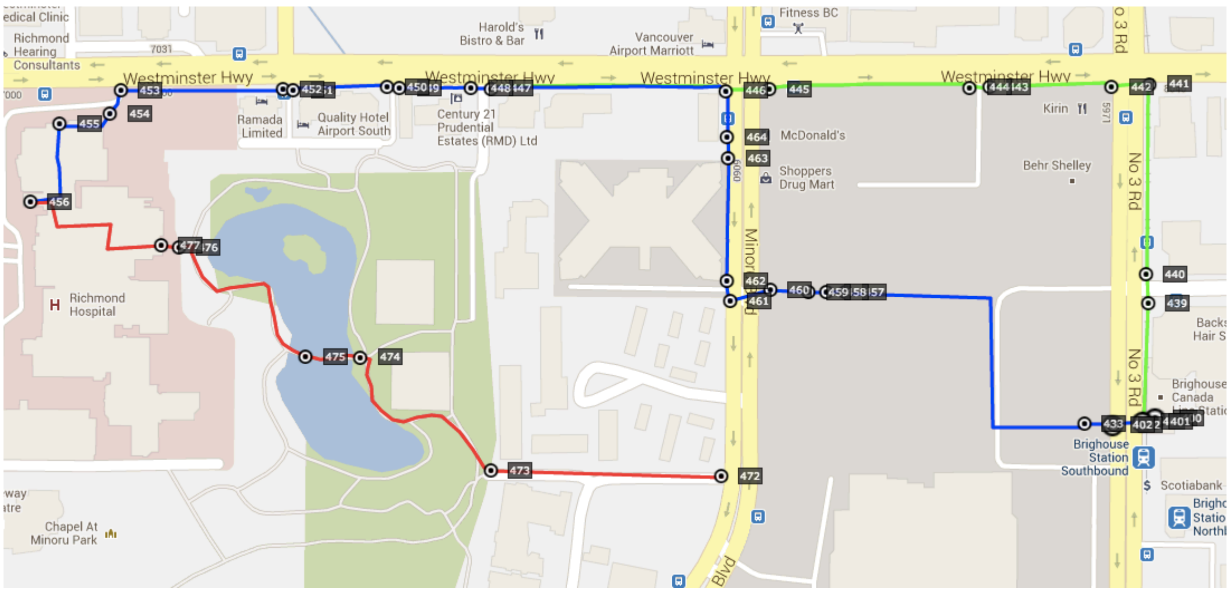


Figure 3.19 Richmond Hospital paths

Table 3.9 Richmond Hospital routes

786 m straight-line distance Walk Score = 93		
Route #	Network Distance (m)	Route
1	1044	north on No. 3, west on Westminster
2	963	west through mall, west through park
3	1058	west through mall, north on Minoru, west on Westminster

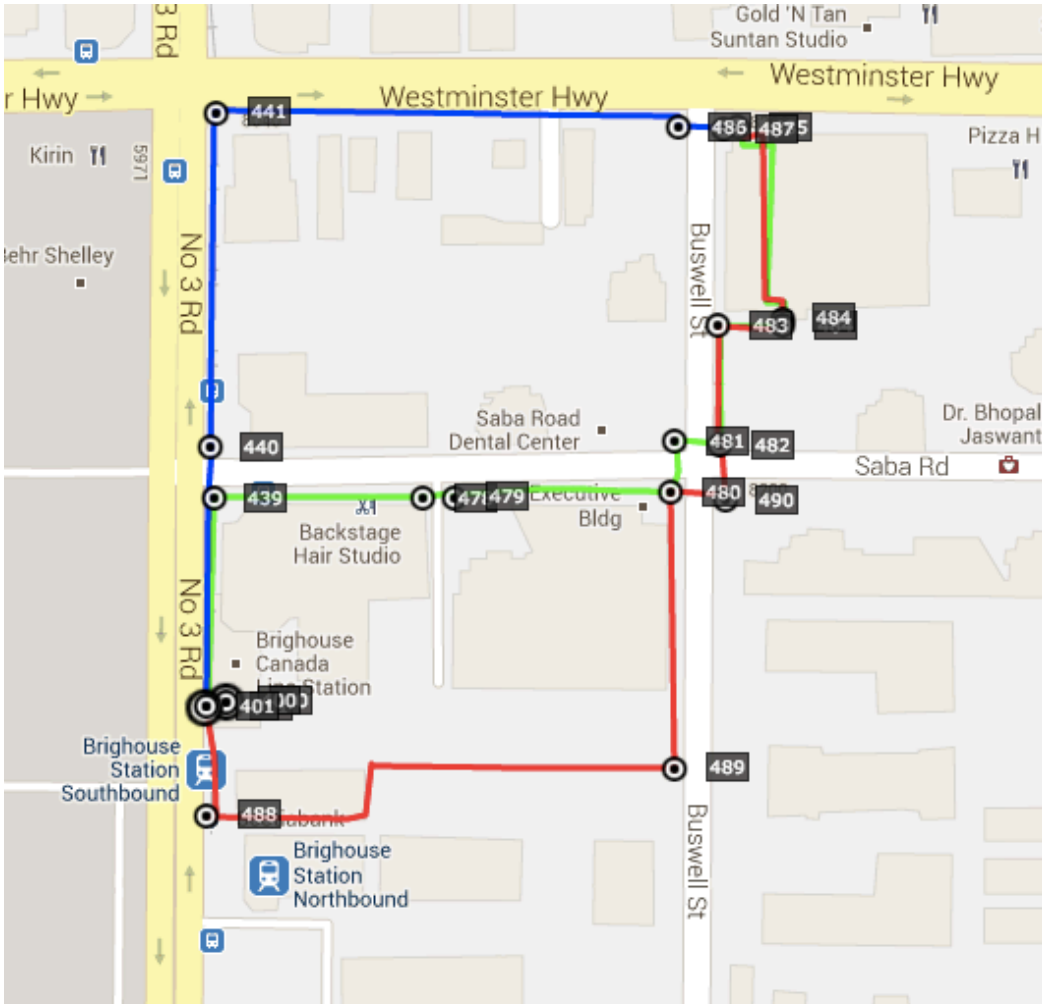


Figure 3.20 Richmond market paths

Table 3.10 Richmond Market routes

786 m straight-line distance Walk Score = 87		
Route #	Network Distance (m)	Route
1	1044	north on No. 3, west on Westminster
2	963	Across and through mall, through park
3	1058	Across and through mall, north Minoru, west on Westminster, entrance

3.8 Data Collection

Data collection is a multi-stage process conducted on and off-site utilizing a series of checklists. The first stage is to create a draft network map of the paths to be assessed. Utilizing satellite imagery like Google Earth provides information about hubs, targeted destinations and possible paths between the two. The second stage involves ground truthing (i.e. validating satellite imagery with real world conditions) and on-site measurement. At this point nodes and links are captured as well as the measures of their attributes. For the purpose of this thesis, the focus is on path conditions.

Assessing links (i.e., path conditions) can be done in a number of ways depending on precision required and resources available. Continuous link assessment means that every time a change in any of the path conditions occurs, a node is added and a new evaluation of the path moving forward is conducted. This offers a very granular level of detail but is very time consuming and will serve as the approach for this research. The value of that level of granularity has to be weighed against the cost of collecting information in that way. Functional link assessment predetermines how links are segmented with a defined parameter like a city block. This approach requires a decision as to how to score the entire block if path conditions vary. One approach is to give the lowest access level across the entire distance. This approach is less time consuming but may overemphasize the impact small segments with poor conditions have on the entire link. A third approach, defined link distance assessment, predetermines link segments by a defined distance interval. Similar to the functional link assessment approach, the link would receive the lowest access level across the entire distance.

Measuring attributes can be done with a variety of scales. The simplest would be the presence or absence of a feature (i.e. Boolean value). A measure might be an integer like number of accessible parking spots. Other numerical measures like slope can be a range of numbers. Because it is not possible to measure slope every time it changes, a range of slope values is proposed (e.g. 0 – 2%, 2 – 5%, 5 – 8.3%, 8.3 – 10%, > 10%) that are based on cutoff points often used in existing standards. More qualitative attributes like evenness or path stability will require more subjective measures like firm, level, and stable. For more subjective measures, examples can be used to ensure consistently like surface stability is indicated by a situation where a bike leaves no track marks as it travels over that surface.

Ideally, attributes and their measures are mutually exclusive and can be objectively measured. A door has a width that can be measured using a tape measure and can have only one value. A parking lot has a number of designated parking spaces relative to its total number of available spots. In the end, caution is necessary to ensure that the attributes and their measures used to define the social topography are useful, valid and accurate.

3.9 Validity, Reliability & Generalizability

Perhaps most importantly, the criteria for research quality, as described by Yin (1989), come down to construct validity, internal validity, external validity, and reliability. In this research:

Construct validity will be addressed by assessing factors that impede travel along paths. To increase the confidence in these measures, 27 separate pathways ranging in length of 200 to 1000m will be assessed (approximately 25km of sidewalks, paths, and trails will be assessed). In addition to this, research, reports, and guidelines that currently exist will serve to bolster construct validity. Further `research will be necessary to fine-tune the weighting of these constructs for data analysis.

Internal validity for an exploratory study is less of an issue, as the study is not trying to predict behaviours but simply provide a foundation for testing them in the future. Because all the variables are clearly defined prior to conducting the research, internal validity can be maintained.

External validity is achieved because the study attempts to provide analytical not statistical generalizations. The findings will be used to support a broader theory – the social topography model introduced in Chapter 3. The model, based on the case study, will be applicable to any urban setting.

Lastly, **reliability** will be maintained through the use of a standardized assessment tool. As well, the designer of the assessment tool will be the only person conducting accessibility assessments.

4 RESULTS AND ANALYSIS

4.1 Introduction

The literature review establishes many of the existing approaches and principles informing community planning practice. The focus is planning and developing places that meet the needs of the average person for the most part. To determine if these principles, including those that address accessibility, are adopted into policy and practice will be examined next. A policy analysis is important to conduct in order to understand the regulatory mechanisms that translate intent and objectives into measurable goals and actions and influence accessibility which is one of the stated research questions (3b) . Policies and the regulations they help create are the starting point for designing and managing active mobility networks. With this knowledge, a community can be held accountable to for their mandate. Policy analysis, and the systemic context it is driven by, also suggests opportunities and levers that can be controlled to exert change. For this research, the policies and regulations of the case study areas serve as a complementary source of information to determine how the accessibility of AMNs are shaped.

The case study results are presented with a focus on differences between Ability Profiles - not between sites. The case study results are analyzed at the node and link level, as well as at the network level (in this case, a simple path is the unit of measure).

4.2 Planning System

Active mobility networks (AMNs) are shaped by the decisions that emerge from the urban planning policies within the social, political, economic, and environmental context in which they exist. These plans are guided by national and sub-national policies and regulations that place limits on what can and cannot be done with land and transportation systems. In Canada, the federal government plays a role in shaping urban planning and AMNs by conducting research, providing grants for large projects (e.g. light rail infrastructure), regular transfers to the provinces, developing and maintaining federal transportation infrastructure (including national parks and trails), enforcing environmental policies, and providing affordable housing through organizations like the Canada Mortgage and Housing Corporation (CHMC).

In particular, the Constitution Act (1982) puts the provinces in charge of establishing lower levels of government like districts, counties, and municipalities (ss. 92, 92(A) and 93). It is the responsibility of the provincial government, to establish municipalities and set the overriding goals and objectives for urban growth and development. In many provinces, regional districts further refine these strategies in collaboration with other agencies, in particular, municipalities. Municipalities then reflect the goals and objectives of regional strategies in their Official Plans. This process is done in consultation with private citizens, not-for-profit agencies, and the business community.

In some provinces, like Ontario, Planning Acts establish the rules of engagement whereas in B.C., the Local Government Act and Community Charter legislation define urban planning responsibilities. In addition to these roles and responsibilities, provincial governments will communicate the vision and objectives that the province seeks to achieve. These high-level statements may be codified, as in Ontario's Provincial Policy Statement, to help direct lower levels of government in their policies. Environmental protection, urban containment, residential and employment density, and integrated systems are important components.

Adoption of urban planning models like Smart Growth and TOD are explicitly communicated through provincial strategies that get funded.

Regional governments, where they exist, are collaborations between municipalities addressing shared concerns (Hodge & Robinson, 2002). AMNs may include park and trail systems that connect municipalities and offer active recreation opportunities. To achieve broader, long-term goals, regional governments are charged with developing sustainable strategies that look deep into the future and across different services (e.g. water supply, transportation systems including transit, parks, etc.). The plan that is developed is then agreed upon by each community and reflected in their own Official Plans (Hodge & Robinson, 2002).

Municipal governments refine regional and provincial objectives to reflect their own context. Official community plans consider the entire city as well as the direct connections it has with neighbouring communities. The city might get broken down into smaller units with their own special plans. Zoning bylaws are the key tools used to designate land uses. As development takes place (e.g. new subdivisions, major capital infrastructure, etc.), plans are amended to incorporate these new land uses. Citizens can seek changes to their own land through bylaw variances (Hodge & Gordon, 2013).

The Official Plan will also include overall plans for transportation, housing, agriculture, and other issues specific to their context. Transportation plans, in particular, knit together the special area plans and link to the broader regional plan. AMNs, therefore, need to be understood across plans and stakeholders in order to be successfully developed and maintained (Hodge & Gordon, 2013). In this section we will focus primarily on the policies that directly impact development in the Lower Mainland of British Columbia where the case studies will be undertaken.

4.2.1 Planning Process

In the formal planning system, codified and predictable processes exist to ensure a fair and orderly process. The rational comprehensive model is widely used as a framework for decisions making throughout the plan making process (Seasons, 2003). This model reflects a continuous process with no final end state other than monitoring and adapting. Plans are to be under constant review to determine actions, revise problems and opportunities, and determine new alternatives. In addition, this model requires that the rationale for decision-making be explicit (Taylor, 1998). The planning process is essentially linear, with opportunities for review at every stage (Hodge & Gordon, 2008). Each stage is linked to preceding stages through feedback loops, allowing for continual redefinition of goals/ opportunities and modification of alternative plans.

- Identifying problems and opportunities
- Establishing goals and objectives
- Collecting data
- Analyzing data
- Developing alternatives
- Choosing solution
- Implementation
- Monitoring and evaluating

A community or region establishes high-level urban plans in order to respond to local issues and aspirations (Gordon & Hodge, 2008). Intrinsic to these plans are long-term goals complemented by action-oriented objectives. These plans take into account current patterns and trends, as well as forecasted future conditions. High-level plans describe a desired vision of the community in realistic terms and provide direction for its achievement. A statement of current political and social values is embedded within the content of the plan (Ryan, 2011).

High-level plans exist to regulate development in accordance with provincial and municipal policies. Hodge and Gordon (2008) contend that high-level municipal plans should include “all significant factors - physical and non-physical, local and regional, that affect physical growth and development of the community” (p. 209). These plans set out land designations and are typically narrative in form with complementary land use maps. There are five basic physical elements of the community plan: natural environment, living areas, working areas, community facilities, and circulation (Hodge & Gordon, 2013). In accordance with these five basic elements, high-level plans are divided into sections that address different areas of planning, including: housing, transportation, economic development, urban form, and the environment. Accompanying design guidelines have historically focused on aesthetic concerns rather than social and economic impacts (Linovski and Loukaitou-Sideris, 2013).

Plans for new subdivisions and special areas that are introduced after an OCP becomes official require amendments to the bylaws before they are allowed to move forward. Development fees are paid to the municipality to initiate this process. Minor changes to individual parcels often only require the owner to obtain a variance from the municipality (open to public input). The municipality and/or higher office adjudicate bigger disputes over planned and existing land uses.

Planning AMNs is part of the broader planning process and has regional and municipal scales. A current approach to addressing the complex transportation challenge is called Transportation Demand Management (TDM). TDM is a set of long-term strategies that solves current and future transportation challenges that influence travel behaviours (Ferguson, 1998). TDM attempts to influence when, where, and how people navigate their environments. Policies and practices are then put into place to reward or discourage certain behaviours. This may take the form of economic incentives/disincentives, capital infrastructure improvements, technological advancements, or broader policy initiatives. For instance, allowing for greater mix-used planning theoretically enables people to live closer to where they work, thus allowing them to walk or bike to work.

Due to their interdependent nature, AMNs are a product of collaboration within planning departments and beyond. Engineering departments must work with urban planners, social planners, cultural planners, architects, landscape architects, as well as the City Manager. AMNs are also a product of external stakeholder input from city government that approve decisions, businesses that seek to enhance their economic position, and the general public that want to preserve or improve their neighbourhoods. These groups are often in conflict and, at the same time, not mutually exclusive, making for a complex challenge for planners (Hodge & Gordon, 2013).

4.2.2 Planning Hierarchy in B.C.

The planning hierarchy in B.C. is defined by two complementary legislative enactments: the Local Government Act (1996) and the Community Charter (2004). Through these two pieces of legislation, community planning responsibilities have been defined. The Local

Government Act requires local governments to promote '…socially, economically and environmentally healthy human settlements that make the best use of public facilities, services, land and other resources" (p. 8). The Community Charter enhances the power of municipalities to be able to address local issues. The City of Vancouver holds a special place in British Columbia. The Vancouver Charter replaces the Community Charter and, "…despite anything in the *Community Charter* or the *Local Government Act* to the contrary, the only provisions of those Acts that apply to the city are the provisions referred to in this Act" (2.1 (3). In British Columbia, 8.5% of municipal budgets go into transportation, 14.5% in to parks and recreation, 9.3% into general government, and 25.8% into capital expenditures that all help shape AMNs (UBCM, 2005). Municipal revenues are a product of development fees (4.9%), service fees (31.1%), taxes (48.5%), and other sources (15.5%).

Other legislation, like the Land Titles Act, regulates the rights for buying and selling land as well as subdividing it. The Environmental Assessment Act and other environment related legislation place parameters on development in environmentally sensitive areas. In the end, AMN policies developed at the municipal level, therefore, must adhere to the rules and regulations of this legal framework. These provincial legislative Acts collectively define the parameters in which AMNs can evolve.

Within the Local Government Act and Community Charter Act are guidelines for establishing Regional Growth Strategies (RGS) that address transportation and land use challenges. Municipal governments are responsible for developing Official Community Plans (OCPs) that follow the objectives of the RGS and are accompanied by a Regional Context Statement that explicitly states how their OCP adheres to the RGS. From these high level policy statements emerge explicit zoning bylaws regulating land uses and reflect the goals of the OCP and RGS. Bylaws restrict not only the size, look, and shape of buildings on a plot of land, but also what activities are allowed on the premises. For instance, in Surrey, the Single Family Residential Zone (RF) allows for one, single family dwelling that may contain 1 secondary suite. Owners of this land can use it as a bed and breakfast or allow boarders and lodgers to stay on the premises. The maximum density is 1 dwelling unit per acre covering a maximum of 40% of the land. Minimum setbacks are 7.5m for the front yard and 1.8m for the side yard and building heights cannot exceed 9m. However, unlike other provinces, British Columbia does not have a provincial agency dedicated to hearing land use disagreements (e.g. Ontario's Municipal Board).

The policy research in this thesis focuses on municipalities (Vancouver, Richmond, and Surrey) that are a part of Metro Vancouver (formerly Greater Vancouver Regional District – GVRD). Key components of these plans that significantly impact the quality and quantity of AMNs is discussed.

4.3 Review of AMN Policy

AMNs are key components of urban and regional planning policies and practices in a society where health and transportation are key issues. The emergence of AMNs, therefore, is dependent upon the planning system as a whole. The following will examine key stakeholders and the formal planning processes that drive policy and decisions in the case study areas. Additional forces also exist (e.g. politics, economy, history, etc.) that influence the planning system but are not addressed here.

4.3.1 Metro Vancouver

The vision of the Metro Vancouver Regional Growth Strategy (2010) is to achieve the "…highest quality of life embracing cultural vitality, economic prosperity, social justice and compassion, all nurtured in and by a beautiful and healthy natural environment" (p. iv). It emphasizes compact and complete community development to achieve many of its objectives. To ward off sprawl urban containment limits have been set (see Figure 4.1) with development targeted at urban centres. The case study locations are all deemed 'urban centres' that serve as focal points for employment, high-density housing, and a mix of commercial, recreational, and entertainment uses (Metro Vancouver, 2012). Development is to be targeted within 800m of rapid transit or 400m of two or more express busses (Frequent Transit Development Areas).

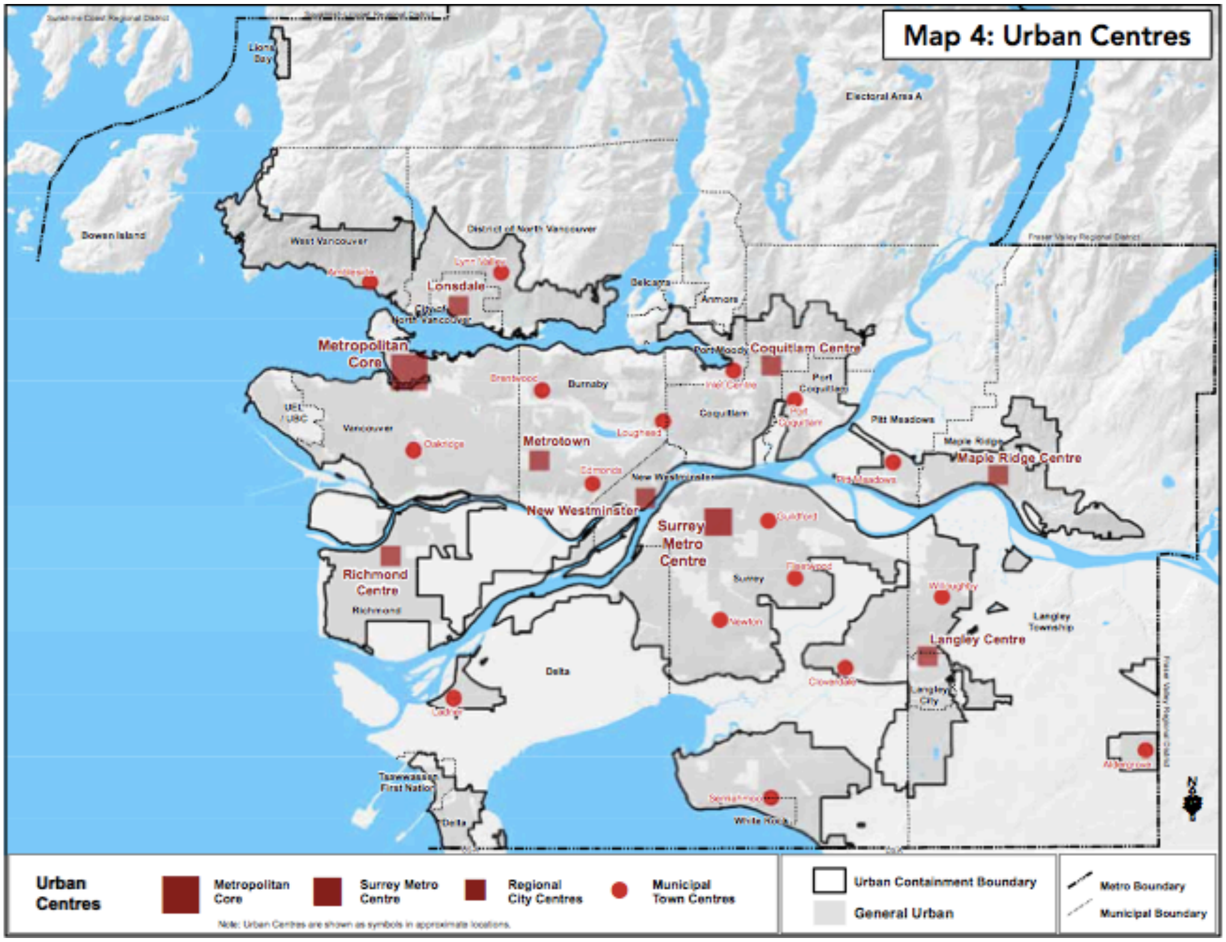


Figure 4.1 Urban Centres (Source: Metro Vancouver, 2010)

The Metro Vancouver plan also calls on measures to encourage land use and transportation infrastructure that are environmentally sustainable and result in 'complete communities' – walkable places with a variety of opportunities and robust transit options. AMNs and transit play a significant role in achieving this objective. A mix of affordable housing choices and range of services enable people of all ages to engage in healthy lifestyles. Complete communities have universally designed park/open spaces, social and cultural amenities, health care facilities, and local food production. This is all supported by a coordinated transportation strategy that connects people efficiently and effectively to the resources that exist in the community, region, and beyond.

The strategy utilizes the following measures to gauge the performance of its relevant goals:

- Compact Urban Areas (Goal 1): residential and employment density within containment boundary
- Environmental Protection (Goal 3): fuel sold for vehicles and transit share
- Complete Communities (Goal 4): # of residences within walking distance of park/trail, public and community recreation facilities, and grocery store
- Sustainable Transportation (Goal 5): kilometres of frequent transit, transit service hours, fuel consumption, commuting distances, traffic accidents

In coordination with TransLink (transit agency), Metro Vancouver also produced a transportation strategy (2008). The plan has six key goals that include reducing greenhouse emissions, increasing active mobility options, increasing employment close to transit, and providing safe and accessible travel options. These are meant to align with the RGS and municipal strategies. Accomplishing this requires collaboration between agencies at all levels of government.

4.3.2 Vancouver

The City of Vancouver (2013) has drafted a Regional Context Statement (RCS) that does not deviate significantly from the Metro Vancouver RGS that was adopted by the city. The RCS was also adopted as the Official Development Plan and provides citywide guidelines, leaving the details to individual Community Plans. According to the RCS, the Broadway corridor is to be treated as a Frequent Transit Development Area. Broadway is the junction point for three Sky Train lines that serve downtown to the northwest, Burnaby and Coquitlam to the east, and Surrey and Richmond to the south. Rapid bus transit providing service to west Broadway and the University of British Columbia can be found along Broadway.

Zoning bylaws support this strategy by allowing for higher densities (including laneway houses, infill development, and subdividing larger plots) in this area and mixed land use development. Residential zoning is to be discouraged in favour of more (and higher) commercial land uses. The RCS also identifies complementary plans like the Vancouver Greenways Plan (1995) and Greenest City 2020 Action Plan as ways to create a seamless network of paths and trails (see Figure 4.2.

Figure 4.2 Vancouver Greenways Plan (Source: City of Vancouver, 1995)

No official community plan exists for the Fairview area of Vancouver that the Broadway Station and its 800m radius encompass, but there is one for the Mount Pleasant neighbourhood to the east (see Figure 4.3). Much of the land is zoned CD-1 (*n*) which is a Comprehensive Development District with the *n* indicating bylaws that are customized for that setting. This area continues to evolve and may have to incorporate light rail transit in its future to better meet the needs of east-west traffic between the University of British Columbia and Simon Fraser University.

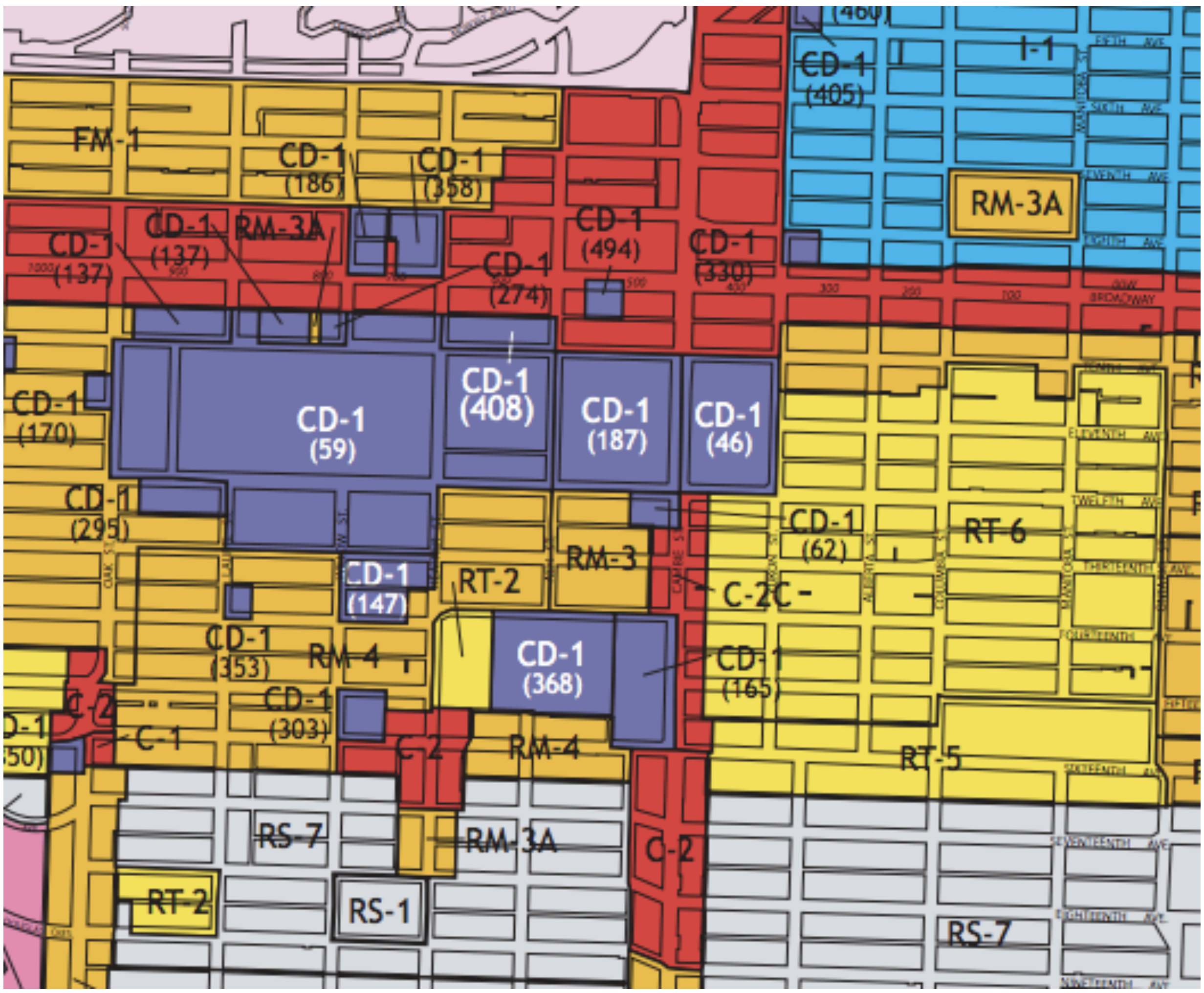


Figure 4.3 Zoning around Broadway SkyTrain station. (Source: City of Vancouver website)

4.3.3 Richmond

Richmond has also adopted the Metro Vancouver RGS and confirms its intentions through its RCS. Urban sprawl is being contained with commercial growth being directed to the city centre (case study area). Density bonuses are offered in these areas to encourage development near transit and reduced parking space requirements. At the heart of the OCP is the City Centre Area Plan and its two key principles: 1) compact and complete communities, and 2) TOD. The City Centre Plan is represented by ever increasing levels of density (see Figure 4.4 & Figure 4.5) and the terminus of the Canada Line (part of the Vancouver Sky Train system) is the centerpiece of the area. The RCS sets out objectives for the AMNs including safe, comfortable and barrier-free walking, cycling routes, and better transit options. Walkable and accessible sidewalks lined with trees and adequate lighting buffered by parking will be at the heart of the street design. Even parking lots will be designed with pedestrians in mind. In addition to transportation planning, land use plans focus on building smaller blocks (< 100m long) with higher densities in the city core.

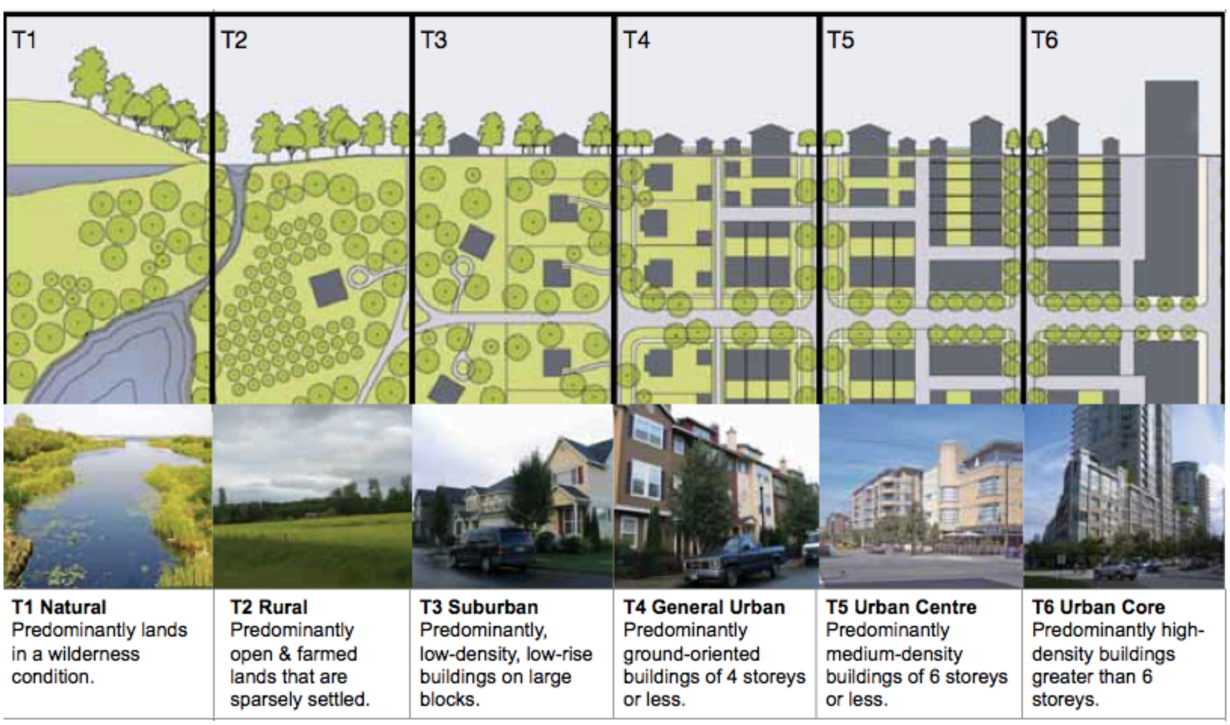


Figure 4.4 Richmond Transect (Source: Richmond OCP)

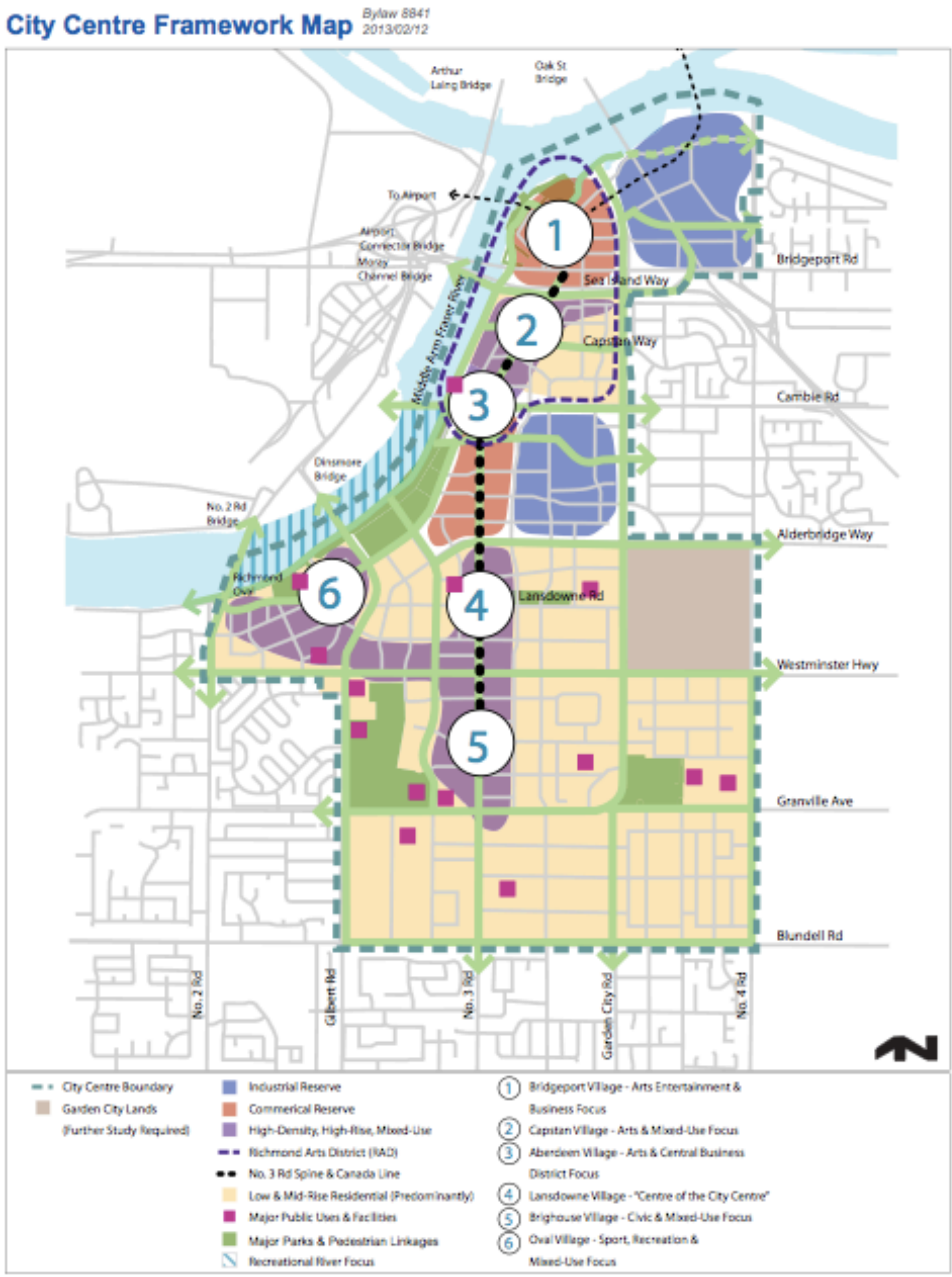


Figure 4.5 Richmond City Centre Framework (Source: Richmond OCP)

4.3.4 Surrey

The City of Surrey, like the other two case study areas, approved the Regional Growth Strategy and incorporated a Regional Context Statement into their Official Plan in 2004. The Official Community Plan – "Strategy for a Sustainable City" establishes a course for Surrey within the Lower Mainland of British Columbia. Particular mention of complete communities, increasing transportation choices, and of course, managing growth is central to the Official Plan.

In order to achieve the goals and objectives of complete communities, compact urban development with small lots, multiple residential dwellings, and mixed-use zoning is endorsed. Efficiency in the transportation choices, including walking and cycling receives some attention. As with the other two locations, significant construction around the SkyTrain station has reshaped the local area. In Surrey's case, construction is still under way.

Of particular interest is Surrey's Walking Plan (2011). In this document, four steps for enhancing the AMN are defined: connectedness, universal access, safe and comfortable streets, and the integration of transportation and land use planning. As part of the transportation strategic plan within this document, a preliminary audit of the walking environment is planned. Priorities around schools are specifically addressed. One of the key actions that may directly influence the accessibility of AMNs is the incorporation of improved accessibility measures into the Design Criteria Manual.

4.4 Case Study Results Overview

The accessibility assessments of the 27 paths resulted in approximately 23.5km of data about city sidewalks and paths in 3 locations in the Lower Mainland of British Columbia, Over

500 nodes and links were assessed in the process (complete data available in Appendix D). The majority of accessibility data collected focused on path conditions, driveway and street crossings and some obstacles and hazards. Some general observations from the study are:

- Path widths were often reduced by the use of multiple surfaces types with gaps between them despite the fact that the pedestrian right-of-way may have been 2m wide or even wider
- Permanent and temporary obstacles like trees, light poles, bike racks, sandwich boards, etc. also reduced path widths
- Cross slopes were within the 2-3% standard but, when coupled with steeper running slopes, present a great challenge for someone in a manual wheelchair and a potential hazard for someone in a power scooter
- Steep cross slopes along driveway crossings along with abrupt dips at either end present a challenge when an individual has to also be concerned with traffic entering and exiting
- Slopes, due to topography, were quite extreme in some places
- Path conditions were generally good where sidewalks actually existed
- Sidewalks in the residential neighbourhoods were incomplete or non-existent in the Surrey location
- Local malls offered easy short-cuts, or slightly longer but easier options
- Hazards involving lane entrances where drivers may not see someone at a lower height are of some concern

The audit results presented below echo many of the observations discussed above. Accessibility audit findings are presented by city (reminder that the intent is not to compare cities but across Ability Profiles). Only the full results for the Vancouver City Hall site are shown. The following key will help the user to interpret the tables:

Ability Profiles (AP):	**Assessment Scores:**
A - Able Bodied	d -distance
P - Paraplegic	u - surface
Q - Quadriplegic	s - slope
S - Scooter	w - width
	h - hazard
	a - final access score

The most basic of information is the percent of all nodes being rated from easy (1) to very difficult (4) for each of the four Ability Profile groups. Table 4.1 shows that a majority of nodes were easy to moderate for the able-bodied group (89.1%) but significantly less so for paraplegics (65.4%), quadriplegics (39.8%), and people using scooters (37.1%).

Table 4.1 Percent of nodes by rating for each Ability Profile.

	Able-Bodied	**Paraplegic**	**Quadriplegic**	**Scooter**
Easy	41.2%	12.8%	5.0%	8.4%
Moderate	47.9%	52.6%	34.8%	28.7%
Difficult	5.3%	23.4%	35.4%	38.2%
Very Difficult	1.9%	7.5%	21.2%	21.2%

Results for paths were relatively similar as for nodes (see

Table 4.2). The conditions for the able-bodied population were much better than the other three Ability Profile groups. 93.07% of paths were easy or moderate for the able bodied group versus 77.42% for paraplegics, 52.68% for quadriplegics, and 44.16% for scooters.

Table 4.2 Percent of paths by rating for each Ability Profile group.

	Able-Bodied	Paraplegic	Quadriplegic	Scooter
Easy	74.85%	10.89%	1.19%	9.31%
Moderate	18.22%	66.53%	51.49%	34.85%
Difficult	5.15%	14.85%	5.94%	46.73%
Very Difficult	1.78%	7.72%	41.39%	9.11%

4.4.1 Discussion of Vancouver Broadway Findings

Table 4.3 presents the accessibility findings for the nodes along the Vancouver City Hall Path #1. They are divided between the four Ability Profile groups (four colours). Within each Ability Profile are the access ratings derived for each of the node attributes (e.g. slope, width, etc.). Table 4.4 presents the accessibility ratings derived for each path between the nodes listed (the From and To columns). Like the node table, the links table is broken down into Ability Profiles. They are further divided into the path conditions (e.g. cross slope, obstacles, etc.). Both tables provide a final access score for the individual node or link in the last column of each Ability Profile.

Table 4.3 Access ratings for each node attribute along Vancouver City Hall Path #1.

AP >	Able-Bodied							Paraplegic							Quadriplegic							Scooter						
ID	**u**	**s**	**c**	**w**	**b**	**h**	**a**	**u**	**s**	**c**	**w**	**b**	**h**	**a**	**u**	**s**	**c**	**w**	**b**	**h**	**a**	**u**	**s**	**c**	**w**	**b**	**h**	**a**
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	2	2	1	1	1	2	1	1	2	1	1	1	2
3	1	1	1	2	1	1	2	1	1	2	3	1	1	3	1	2	2	3	1	1	3	1	1	2	4	1	1	4
4	1	1	1	1	1	1	1	1	1	3	2	1	1	3	1	2	4	2	1	1	4	1	1	3	3	1	1	3
5	1	1	1	1	1	1	1	1	1	2	2	1	1	2	1	2	2	2	1	1	2	1	1	2	3	1	1	3
6	1	1	1	1	1	1	1	1	1	3	2	1	1	3	1	2	3	2	1	1	3	1	1	3	4	1	1	4
7	1	1	1	1	1	1	1	1	1	3	2	1	1	3	1	2	3	2	1	1	3	1	1	3	3	1	1	3
8	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	2	2	1	1	1	2	1	1	2	1	1	1	2
9	1	2	1	1	1	1	2	1	2	2	1	1	1	2	1	3	2	1	1	1	3	1	1	2	2	1	1	2
10	1	2	1	1	1	1	2	1	3	2	2	1	1	3	1	4	2	2	1	1	4	1	2	2	3	1	1	3
11	1	2	1	1	1	1	2	1	2	3	2	1	1	3	1	3	3	2	1	1	3	1	1	3	3	1	1	3
12	1	1	1	1	1	2	2	1	1	2	2	1	2	2	1	2	2	2	1	2	2	1	1	2	3	1	2	3
13	1	1	1	1	1	1	1	1	1	2	2	1	1	2	1	2	2	2	1	1	2	1	1	2	3	1	1	3
14	1	2	1	1	1	1	2	1	2	3	2	1	1	3	1	3	3	2	1	1	3	1	1	3	3	1	1	3
15	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	2	2	1	1	1	2	1	1	2	2	1	1	2
16	1	2	1	1	1	1	1	1	3	2	1	1	1	1	1	4	2	1	1	1	1	1	2	2	2	1	1	1
17	1	2	1	1	1	1	1	1	2	2	2	1	1	1	1	3	2	2	1	1	1	1	1	2	3	1	1	1
18	1	2	1	1	1	1	2	1	3	3	2	1	1	3	1	4	3	2	1	1	4	1	2	3	3	1	1	3
19	1	2	1	1	1	1	2	1	2	2	2	1	1	2	1	3	2	2	1	1	3	1	1	2	3	1	1	3
20	1	1	1	1	1	2	2	1	1	3	2	1	2	3	1	2	3	2	1	2	3	1	1	3	4	1	2	4
21	1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	2	1	1	2	1	1	1	4	1	1	4
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	2	1	1	1	1	2	1	3	1	2	1	1	3	1	4	1	2	1	1	4	1	2	1	3	1	1	3
24	1	2	1	1	1	2	2	1	2	1	2	2	2	2	1	3	2	2	3	2	3	1	1	1	4	2	2	4
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 4.4 Access ratings for path conditions along Vancouver City Hall Path #1.

Path Ratings (by Ability Profile)											A						P						Q						S					
From	A	P	Q	S	To	A	P	Q	S	d	u	s	c	w	h	a	u	s	c	w	h	a	u	s	c	w	h	a	u	s	c	w	h	a
1	1	1	1	1	2	1	2	4	2	16	1	1	1	1	1	1	1	2	1	1	1	2	1	4	1	1	1	4	1	1	1	1	1	1
2	1	2	2	2	3	2	4	4	4	27	1	1	1	2	1	2	1	1	2	3	1	3	1	2	2	3	1	3	1	1	2	4	1	4
3	2	4	3	4	4	1	3	4	3	15	1	1	1	1	1	1	1	1	2	2	1	2	1	2	2	2	1	2	1	1	2	3	1	3
4	1	3	4	3	5	1	2	4	2	13	1	1	1	1	1	1	1	2	3	2	1	3	1	4	4	2	1	4	1	1	3	3	1	3
5	1	2	2	3	6	1	3	4	4	18	1	1	1	1	1	1	1	1	2	2	1	2	1	2	2	2	1	2	1	1	2	3	1	3
6	1	3	3	4	7	1	3	4	3	13	1	1	1	1	1	1	1	2	3	1	1	3	1	4	4	1	1	4	1	1	3	2	1	3
7	1	3	3	3	8	1	2	4	2	20	1	1	1	1	1	1	1	1	2	2	1	2	1	2	2	2	1	2	1	1	2	3	1	3
8	1	2	2	2	9	1	2	4	2	88	1	3	1	1	1	3	1	4	2	2	1	4	1	4	2	2	1	4	1	3	2	3	1	3
9	1	2	3	2	10	2	3	4	2	12	1	1	1	1	1	1	1	2	2	2	1	2	1	4	2	2	1	4	1	1	2	3	1	3
10	2	3	4	3	11	1	3	4	3	32	1	3	1	1	1	3	1	4	2	2	1	4	1	4	2	2	1	4	1	3	2	3	1	3
11	1	3	3	3	12	2	2	4	2	12	1	3	1	1	1	3	1	4	2	1	1	4	1	4	2	1	1	4	1	3	2	1	1	3
12	2	2	2	3	13	1	2	4	2	48	1	3	1	1	2	3	1	4	3	1	3	4	1	4	4	1	3	4	1	3	3	2	3	3
13	1	2	2	3	14	1	3	4	3	10	1	3	1	1	1	3	1	4	2	2	1	4	1	4	2	2	1	4	1	3	2	3	1	3
14	1	3	3	3	15	1	2	4	2	25	1	1	1	1	1	1	1	2	2	2	1	2	1	4	2	2	1	4	1	1	2	3	1	3
15	1	2	2	2	16	0	0	0	0	10	1	1	1	1	1	1	1	2	3	2	1	3	1	3	4	2	1	4	1	1	3	3	1	3
16	0	0	0	0	17	0	0	0	0	4	1	1	1	1	1	1	1	2	2	2	1	2	1	4	2	2	1	4	1	1	2	3	1	3
17	0	0	0	0	18	2	3	4	3	13	1	1	1	1	1	1	1	2	2	2	1	2	1	4	2	2	1	4	1	1	2	3	1	3
18	2	3	4	3	19	1	2	4	2	30	1	1	1	1	1	1	1	2	2	2	1	2	1	4	2	2	1	4	1	1	2	3	1	3
19	1	2	3	3	20	2	3	4	4	42	1	1	1	1	1	1	1	1	2	2	1	2	1	2	2	2	1	2	1	1	2	3	1	3
20	2	3	3	4	21	1	3	4	4	10	1	1	1	1	1	1	1	1	1	2	1	2	1	1	1	2	1	2	1	1	1	3	1	3
21	1	3	2	4	22	1	1	4	1	10	1	1	1	1	1	1	1	1	1	2	1	2	1	1	1	2	1	2	1	1	1	3	1	3
22	1	1	1	1	23	2	3	4	2	19	1	1	1	1	1	1	1	1	2	2	1	2	1	2	2	2	1	2	1	1	2	3	1	3
23	2	3	4	3	24	2	3	4	4	9	1	2	1	1	1	2	1	3	1	2	1	3	1	4	1	2	1	4	1	2	1	3	1	3
24	2	3	3	4	25	1	1	4	1	21	1	1	1	1	1	1	2	1	1	2	1	2	3	1	1	2	1	3	1	1	1	3	1	3

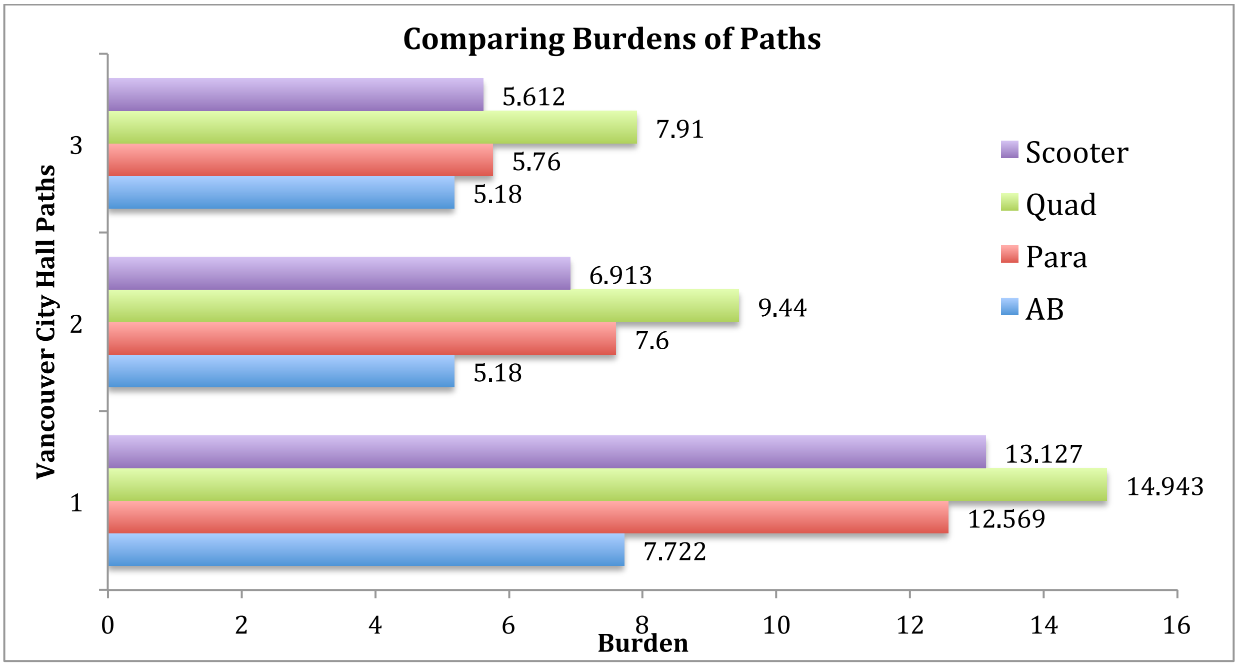


Figure 4.6 Path burdens of Vancouver City Hall paths.

The previous tables offer the raw scores for nodes and links whereas the following tables condense the findings into clear path findings. These tables can be used to build more complex path and network maps. Figure 4.6 summarizes the difference in cumulative burden experienced using the three options for Vancouver City Hall destination. The detailed tables (Table 4.5, Table 4.6, and Table 4.7) present the following information for each of the three options:

- From (start node)
- To (end node)
- β (calculated burden of that link segment for each Ability Profile group)
- a_N (access rating for that node for each Ability Profile group)
- a_P (access rating for that path segment for each Ability Profile group)
- d (distance in metres)

The colour coding is used to make it easier to determine the accessibility of each link.

	Easy		Moderate		Difficult		Very Difficult

By scanning down a column for each Ability Profile group, a picture of where the challenges exist in terms of absolute barriers of nodes and paths as well as the relative burden of the path conditions can be seen. The access rating values are important as is the transitions between segments. Paths that vary from 1 to 3, for example, will quickly frustrate the person traveling. Data in this format also highlights where extended sections of paths have easier or more difficult conditions.

Table 4.5 Vancouver City Hall Path #1 assessment.

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_N	a_P	β	a_N	a_P	d
1	2	0.160	1	1	0.213	1	2	0.320	1	4	0.160	1	1	16
2	3	0.288	1	1	0.485	2	3	0.575	2	3	0.503	2	4	27
3	4	0.275	2	1	0.440	3	2	0.490	3	2	0.575	4	3	15
4	5	0.130	1	1	0.484	3	3	0.722	4	4	0.449	3	3	13
5	6	0.180	1	1	0.353	2	2	0.413	2	2	0.490	3	3	18
6	7	0.130	1	1	0.475	3	3	0.588	3	4	0.566	4	3	13
7	8	0.200	1	1	0.503	3	2	0.570	3	2	0.517	3	3	20
8	9	1.467	1	3	2.120	2	4	2.120	2	4	1.885	2	3	88
9	10	0.245	2	1	0.317	2	2	0.522	3	4	0.285	2	3	12
10	11	0.658	2	3	0.975	3	4	1.100	4	4	0.890	3	3	32
11	12	0.325	2	3	0.514	3	4	0.514	3	4	0.474	3	3	12
12	13	0.957	2	3	1.341	2	4	1.437	2	4	1.338	3	3	48
13	14	0.167	1	3	0.352	2	4	0.352	2	4	0.450	3	3	10
14	15	0.375	2	1	0.650	3	2	0.817	3	4	0.583	3	3	25
15	16	0.100	1	1	0.305	2	3	0.358	2	4	0.278	2	3	10
16	17	0.000	1	1	0.000	1	2	0.000	1	4	0.000	1	3	4
17	18	0.000	1	1	0.000	1	2	0.000	1	4	0.000	1	3	13
18	19	0.425	2	1	0.730	3	2	1.055	4	4	0.650	3	3	30
19	20	0.545	2	1	0.657	2	2	0.922	3	2	0.810	3	3	42
20	21	0.225	2	1	0.357	3	2	0.357	3	2	0.488	4	3	10
21	22	0.100	1	1	0.232	2	2	0.232	2	2	0.488	4	3	10
22	23	0.190	1	1	0.241	1	2	0.304	1	2	0.253	1	3	19
23	24	0.245	2	2	0.406	3	3	0.561	4	4	0.382	3	3	9
24	25	0.335	2	1	0.419	2	2	0.614	3	3	0.613	4	3	21
		7.72			12.57			14.94			13.127			517

Table 4.6 Vancouver City Hall Path #2 assessment.

		A			P					S				
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
1	2	0.160	1	1	0.213	1	2	0.320	1	4	0.160	1	1	16
2	26	0.110	1	1	0.242	2	2	0.242	2	2	0.250	2	3	11
26	27	0.945	2	1	1.437	2	2	2.109	3	4	1.218	2	3	82
27	28	0.425	2	3	0.533	2	4	0.658	3	4	0.485	2	3	18
28	29	0.185	2	1	0.217	2	2	0.382	3	4	0.201	2	2	6
29	30	1.483	1	3	2.017	1	4	2.017	1	4	1.780	1	3	89
30	31	0.315	2	1	0.554	3	2	0.806	4	4	0.503	3	3	19
31	32	0.592	2	3	0.885	3	4	1.010	4	4	0.810	3	3	28
32	33	0.430	1	1	0.545	1	2	0.688	1	2	0.573	1	3	43
33	34	0.555	2	1	0.795	3	2	0.938	3	2	0.823	3	3	43
34	35	0.225	2	1	0.35	3	1	0.508	4	2	0.357	3	2	10
35	36	0.215	2	1	0.346	3	2	0.376	3	2	0.352	3	3	9
36	23	0.210	1	1	0.391	2	2	0.586	3	2	0.405	2	3	21
23	24	0.245	2	2	0.406	3	3	0.561	4	4	0.382	3	3	9
24	25	0.335	2	1	0.419	2	2	0.614	3	3	0.613	4	3	21
		5.18			7.60			9.44			6.91			425

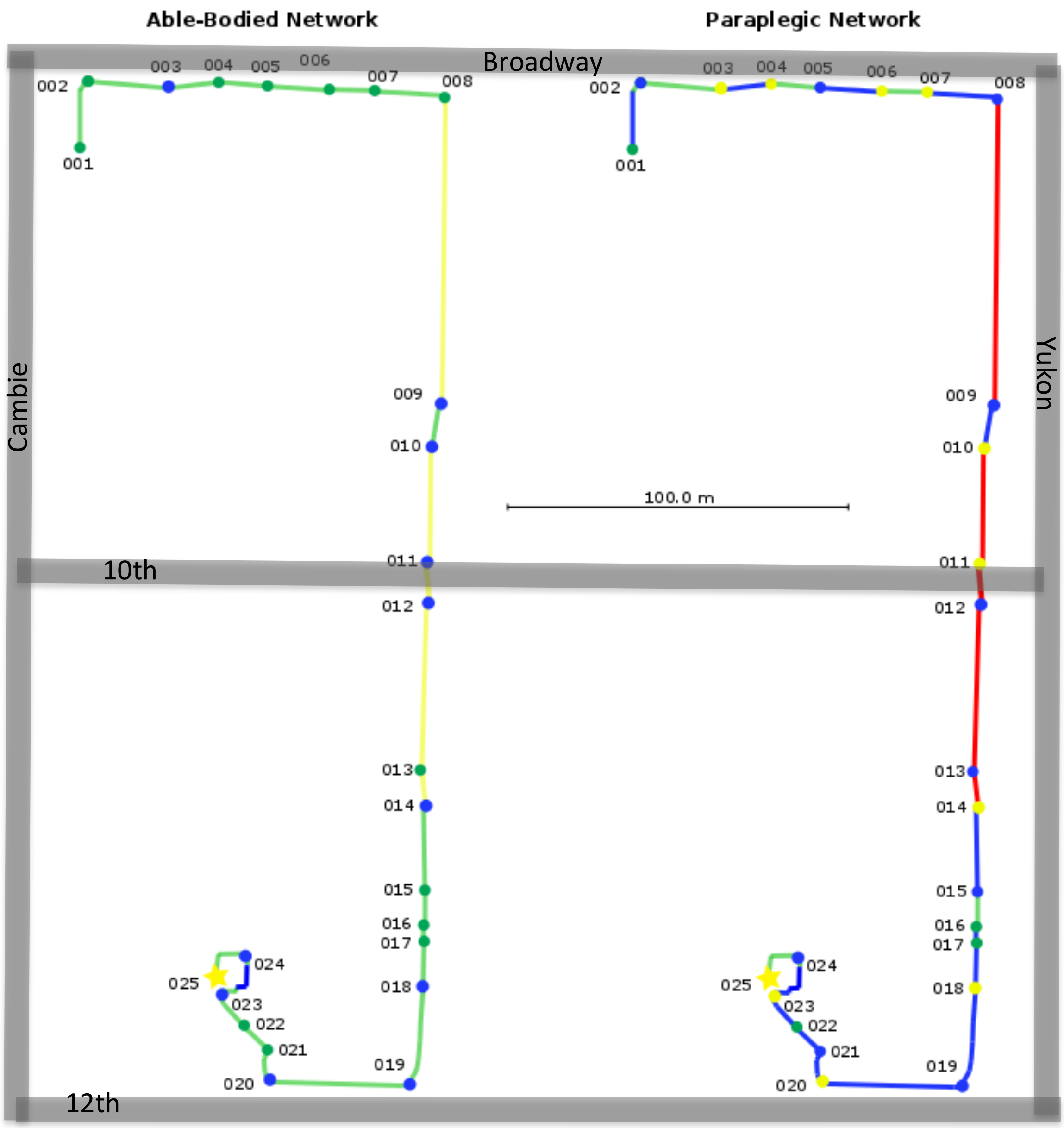
Table 4.7 Vancouver City Hall Path #3 assessment.

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
1	2	0.160	1	1	0.213	1	2	0.32	1	4	0.16	1	1	16
2	26	0.110	1	1	0.264	2	2	0.301	2	2	0.272	2	3	11
26	27	0.945	2	1	1.164	2	2	1.562	3	2	1.218	2	3	82
27	28	0.305	2	1	0.353	2	2	0.538	3	2	0.365	2	3	18
28	29	0.185	2	1	0.201	2	2	0.346	3	2	0.205	2	3	6
29	37	0.100	1	1	0.127	1	2	0.16	1	2	0.133	1	3	10
37	38	1.340	1	1	1.697	1	2	2.144	1	2	1.787	1	3	134
38	25	1.010	1	1	1.741	2	2	2.539	3	3	1.472	2	3	101
		4.16			5.76			7.91			5.61			378

The three City Hall paths require going up a very steep road (Cambie Street) to a front entrance on the north side of 12th Avenue. Because of the size of the City Hall complex, there is just one street crossing Cambie Street to its west and Yukon Street to its east. The three choices range from 378m which utilizes a park and back entrance. Construction to the southwest parking and stairs may provide an entry to the back entrance in between the path cutoff to the north and 12th Avenue, lessening the impact of the slope. There are no public entry points on 10th Avenue, a much shorter distance from the SkyTrain station.

Overall, the three choices offer an easy to moderate option for able-bodied profiles punctuated by a 100m stretch of more difficult slopes. For paraplegics and quadriplegics, there are a number of nodes and links that are very difficult. Path conditions were generally good, with easy to moderate crossings throughout. Path options ranged from a burden of of 4.2 to 7.7 for the able-bodied group with a range of absolute access scores of 1 to 3 for paths and nodes. Paraplegics had burden ranges of 5.8 to 12.6 and absolute access ranges of 1 to 4. Quadriplegics had burden ranges of 7.9 to 14.9 and absolute access ranges of 1 to 4.Lastly, scooters had burden ranges of 5.6 to 13.1 and absolute access ranges of 1 to 4.

The following four figures provide visual representations of some of this data for each of the four Ability Profile groups. The colours used for the nodes and lines represent the accessibility ratings (same colour coding as used in the tables above). The paths and nodes are drawn in reference to where they are physically located (i.e. a layer that could be extracted from a geographic information system). The maps accentuate the steep slope as well as the short plateaus that exist at Broadway, 10th Avenue, and 12th Avenue.



Able-Bodied Network
Paraplegic Network
Broadway
Cambie
Yukon
10th
12th
100.0 m
001
002
003
004
005
006
007
008
009
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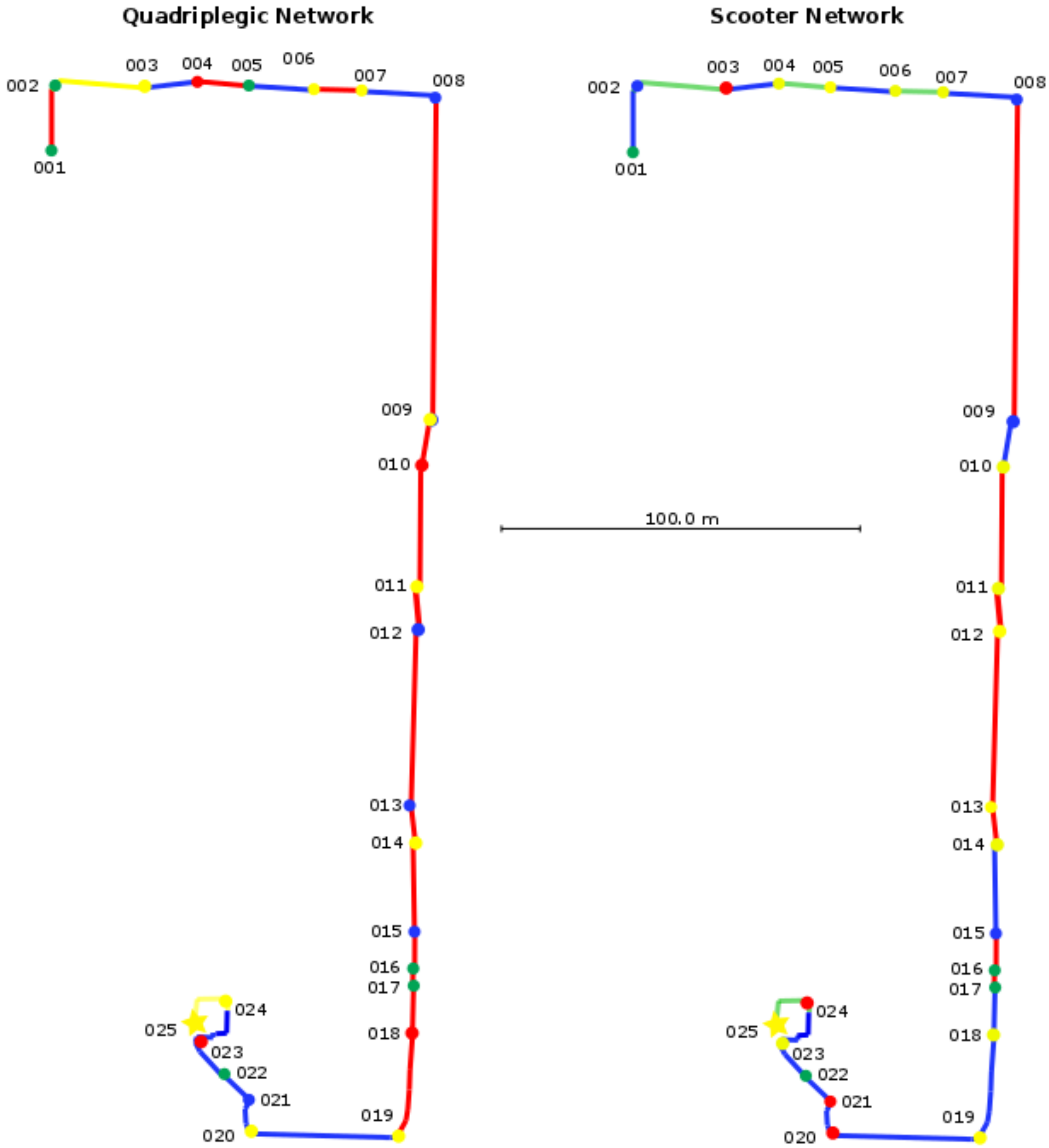
Quadriplegic Network
001
002
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021
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023
024
025
Scooter Network
001
002
003
004
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023
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025
100.0 m

The Vancouver Hospital pathways follow the east–west corridors of Broadway and 12th Avenue, making for longer flat sections. The challenge of a steep climb south down Cambie Street is a little less pronounced the further west you travel. However, Broadway offers the challenge of a busy, cluttered street with bike racks, bus stops, sandwich boards, and driveways with poor visibility for drivers. Sidewalk surfaces are in good shape except for a key driveway crossing that has busy traffic waiting to enter a parking lot that is often full during the day. Cars can be seen blocking the sidewalk as they await their opportunity to enter the lot. Upon reaching the top of the hill to 10th Avenue, getting to the hospital through the rear entrance does require going through an unprotected parking lot for a short duration. Because drivers are often looking for an open parking space, they may not see someone who is at a lower height. Also, where there is a sidewalk into the building, it becomes narrow.

The option that goes through the tunnels connecting health care facilities is not well known. It brings to light the informal networks that exist offering significant potential for better accessibility in many downtown areas where they are more prevalent. Signage through BC Cancer Agency is poor and misleading at times. Safety may be a concern and it is not known if this option is always available (i.e. closed at night).

The paths to Millyard result in similar findings with steep slopes down to 6th Avenue. The sidewalks all have good surface conditions, are sufficiently wide, and offer options onto either side of all the streets should construction block anything. This is a very busy pedestrian and cyclist corridor for those crossing the Cambie Street bridge into downtown Vancouver. However, obstacles like stairs and a railroad track going into the East False Creek residential area present a unique challenge not found in the other study areas. A ramp exists behind an area with bushes that is difficult to see in the summer when plant life is teeming. The residential section has more of a shared space feel to it as well so reliance on sidewalks is not as critical. This, however, is a safety hazard for people who are harder to see because they are at a reduced height.

4.4.2 Discussion of Surrey City Centre Findings

The Surrey City Centre case study area is still under considerable construction to the west and northwest of the SkyTrain station. University Avenue is blocked going north and the sidewalks and crosswalks going east west are compromised. The station is conveniently located beside major recreational facilities and across the street from City Hall and a commercial mall. Pathways in and around station are flat with excellent surfaces. Streets are not as much in a grid around centre as is the case in Vancouver and Richmond. King George Boulevard one block to the east is a very busy street with crossing at Old Yale, 102 Ave, and 104 Ave, 400m and 420m apart respectively, limiting travel options for pedestrians.

The main entrance of the mall even has differentiated surfaces to help those with visual impairments to navigate the large open space that exists. Bollards installed to control traffic are designed for seating but are not accessible. Due to the heavy rains, much of the street furniture was not present and navigating this when there is heavier usage may be a challenge.

Conditions outside the central core are much more variable. Many of the residential areas to the west and south have one or no sidewalks and light standards are occasionally in the middle of the sidewalk. Stairs (Node 307) provide an excellent shortcut to the Fitness Centre but the traveler would not be aware of them until they traveled over 100m to get to them. Slope is a factor as it is in Vancouver but over shorter distances. Getting to the 99A residence requires utilizing a very difficult sidewalk at 132 Street and Old Yale (Node 214). It is one of many examples of a “double dip” curb cut. This type of curb has a steep down slope that ends with a short, but steep, upslope on the street crosswalk. This is a very dangerous situation for a wheelchair and even scooter, as the front footplate may not clear the street upslope and causes the wheelchair to come to an abrupt stop sending the occupant forward and out of the chair. Another common occurrence for the 99A and Kwantlen paths are driveway crossings with steep cross slopes ending in steep upslope. Lastly, there are a couple of pedestrian islands that could barely fit 2 people standing with extremely steep curb cuts that are unusable by anyone in a chair (and hold almost no value to someone walking based on their positioning).

4.4.3 Discussion of Richmond Brighouse Findings

Richmond Brighouse station is in the centre of downtown Richmond. The land in the area, and throughout Richmond, is quite flat. Sidewalks are relatively wide, firm, level, and even. Cross slope is at the typical 2% throughout. This study area has more storefront parking than the other 2 areas allowing for informal travel options that include obstacles for wheelchairs. These informal routes present safety hazards for most pedestrians and more so for those who are harder to see because of height considerations.

The option to travel through the mall to the rear entrance of City Hall, while being longer than the other 2, offers benefits like shopping, dining and rest areas. However, the most direct entrance through the back of the Sears store requires going through a parkade and up a difficult to find path. A similar shortcut to Richmond Hospital that goes through a park with very nice scenery requires going through what appears to be private property (but is not) and through a door that has a knob handle that is difficult for someone who cannot grasp and twist with his or her hands. Steep banks at the end of the trail may require rerouting that would make the distance traveled significantly greater. In bad weather, this option becomes much more difficult in the form of mud and debris.

4.4.4 Composite Node Analysis

The results of the accessibility assessments of the nodes and links do provide some insights about the overall accessibility of the case study areas. The following tables show how nodes fared overall in terms of the 6 key measures (u,s,c,w,b,h) and the final access rating (a). Data is presented for each Ability Profile group in separate tables. The final column is the percent of nodes that reached that final accessibility rating.

Table 4.8 Able Bodied Accessibility Ratings by Node Attribute

	u	s	c	w	b	h	a	% Rating
1	348	176	359	330	354	316	148	96.9%
2	9	178	0	14	3	33	172	2.5%
3	2	4	0	9	2	10	19	0.6%
4	0	1	0	6	0	0	7	0.0%

Table 4.9 Paraplegic Accessibility Ratings by Node Attribute

	u	s	c	w	b	h	a	% Rating
1	347	176	136	154	330	316	46	12.8%
2	1	138	171	176	12	33	189	52.6%
3	10	40	52	14	12	0	84	23.4%
4	1	5	0	15	5	10	27	7.5%

Table 4.10 Quadriplegic Accessibility Ratings by Node Attribute

	u	s	c	w	b	h	a	% Rating
1	347	50	64	154	322	316	18	5.0%
2	1	126	243	176	8	33	125	34.8%

3	0	138	45	14	12	0	127	35.4%
4	11	45	7	15	17	10	76	21.2%

Table 4.11 Scooter Accessibility Ratings by Node Attribute

	u	*s*	*c*	*w*	*b*	*h*	*a*	% Rating
1	347	314	136	68	330	316	30	8.4%
2	10	40	171	86	12	33	103	28.7%
3	2	3	51	135	12	0	137	38.2%
4	0	2	1	70	5	10	76	21.2%

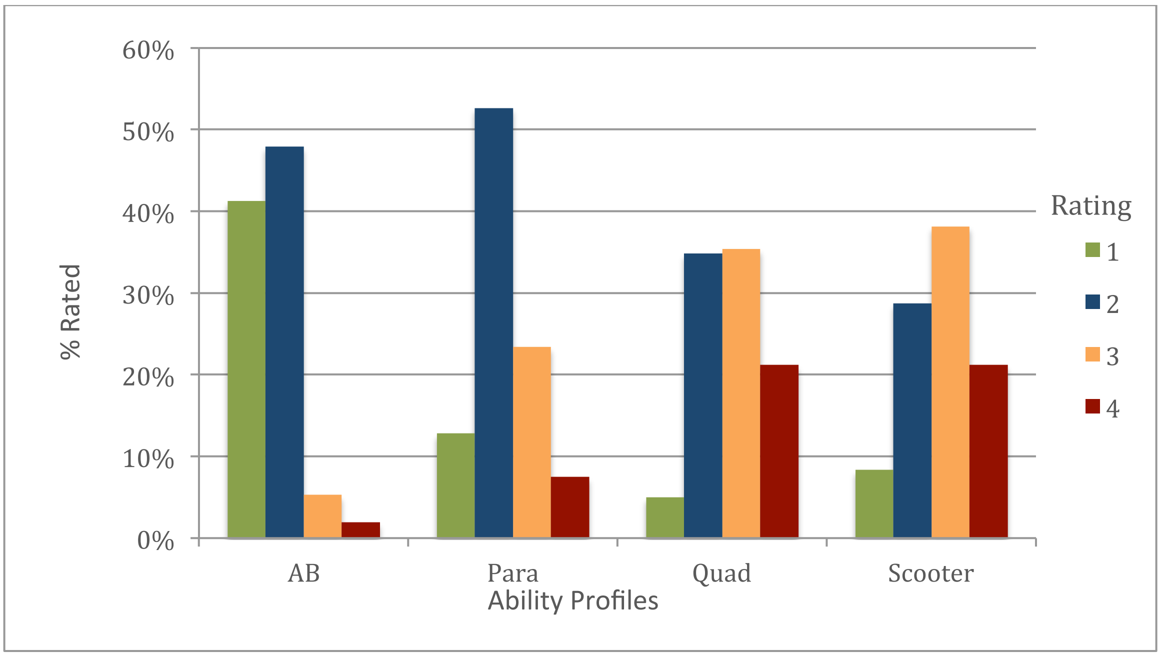

Figure 4.7 Distribution of Node Ratings by Ability Profile Group

The differences in access ratings differ between Ability Profile groups (see Figure 4.7). For the able-bodied population, nodes were easy 41.2% of the time (n=148) or moderate 47.9% of the time (n=172) in difficulty versus difficult or very difficult 10.9% of the time. This is in contrast to that for the disability groups where only 65.4% of paths were good or moderate for paraplegics, 39.8% for quadriplegics, and 37.1% for scooters.

4.4.5 Composite Link Analysis

A similar analysis used for understanding nodes is used to examine the prevalence of accessibility challenges in the actual paths that connect the nodes. The tables below break down the path condition ratings across each Ability Profile group. The trends are similar to the node data. The able bodied group has better overall ratings. 93.1% of all paths were easy to moderate for the able-bodied group, 77.42% for paraplegics, 52.7% for quadriplegics, and 44.2% for scooter users.

Table 4.12 Able Bodied Accessibility Ratings by Path Condition

Access Rating	u	s	c	w	h	a
1	501	447	505	482	441	378
2	4	35	0	11	64	92
3	0	23	0	3	0	26
4	0	0	0	9	0	9

Table 4.13 Paraplegic Accessibility Ratings by Path Condition

Access Rating	u	s	c	w	h	a
1	461	323	133	246	441	55
2	36	124	326	236	0	336
3	4	35	46	11	49	75
4	4	23	0	12	15	39

Table 4.14 Quadriplegic Accessibility Ratings by Path Condition

Access Rating	u	s	c	w	h	a
1	461	56	50	246	441	6
2	0	267	409	236	0	260
3	36	1	0	11	49	30
4	8	181	38	12	15	209

Table 4.15 Scooter Accessibility Ratings by Path Condition

Access Rating	u	s	c	w	h	a
1	497	447	133	99	441	47
2	8	35	326	147	0	176
3	0	19	41	219	49	236
4	0	4	5	40	15	46

Table 4.16 Access Ratings of Paths for each Ability Profile group

	Able-bodied	Paraplegic	Quadriplegic	Scooter
1	74.85%	10.89%	1.19%	9.31%
2	18.22%	66.53%	51.49%	34.85%
3	5.15%	14.85%	5.94%	46.73%
4	1.78%	7.72%	41.39%	9.11%

Table 4.17 depicts the number of times a path condition was the most difficult factor without being the same as any other path condition. In other words, if the access scores were 2 for all path conditions, this would not be counted towards being the dominant factor. However, if 5 of the path conditions were rated a 2 and 1 was a 3, that 1 path condition is the dominant path condition.

Table 4.17 Frequency for a Path Condition to be the Access Rating Determinant

Path Condition	Able-bodied	Paraplegic	Quadriplegic	Scooter
Surface	2	3	0	0
Slope	127	33	7	15
Cross Slope	0	66	35	48
Width	14	37	35	12
Obstacle	4	11	3	3
Hazard	13	3	1	3

The predominant finding here is that more than 1 path condition was a deciding factor in the final access score for a minority of links. Of the 505 links assessed, the able-bodied Ability Profile group only had 38.9% decided by a single factor, 20.2% for paraplegics, 16.0% for quadriplegics, and 16.0% for scooter users. The implication of this is that improving access will require addressing more than one issue at a time.

These path conditions when combined and over a distance create a burden on the traveler. Figures plot out the burden for each of the Ability Profile groups over the length of a chosen path. For both paths, the quadriplegic group has nearly twice the burden as the able-bodied group while the other two are almost 1.5 times the burden.

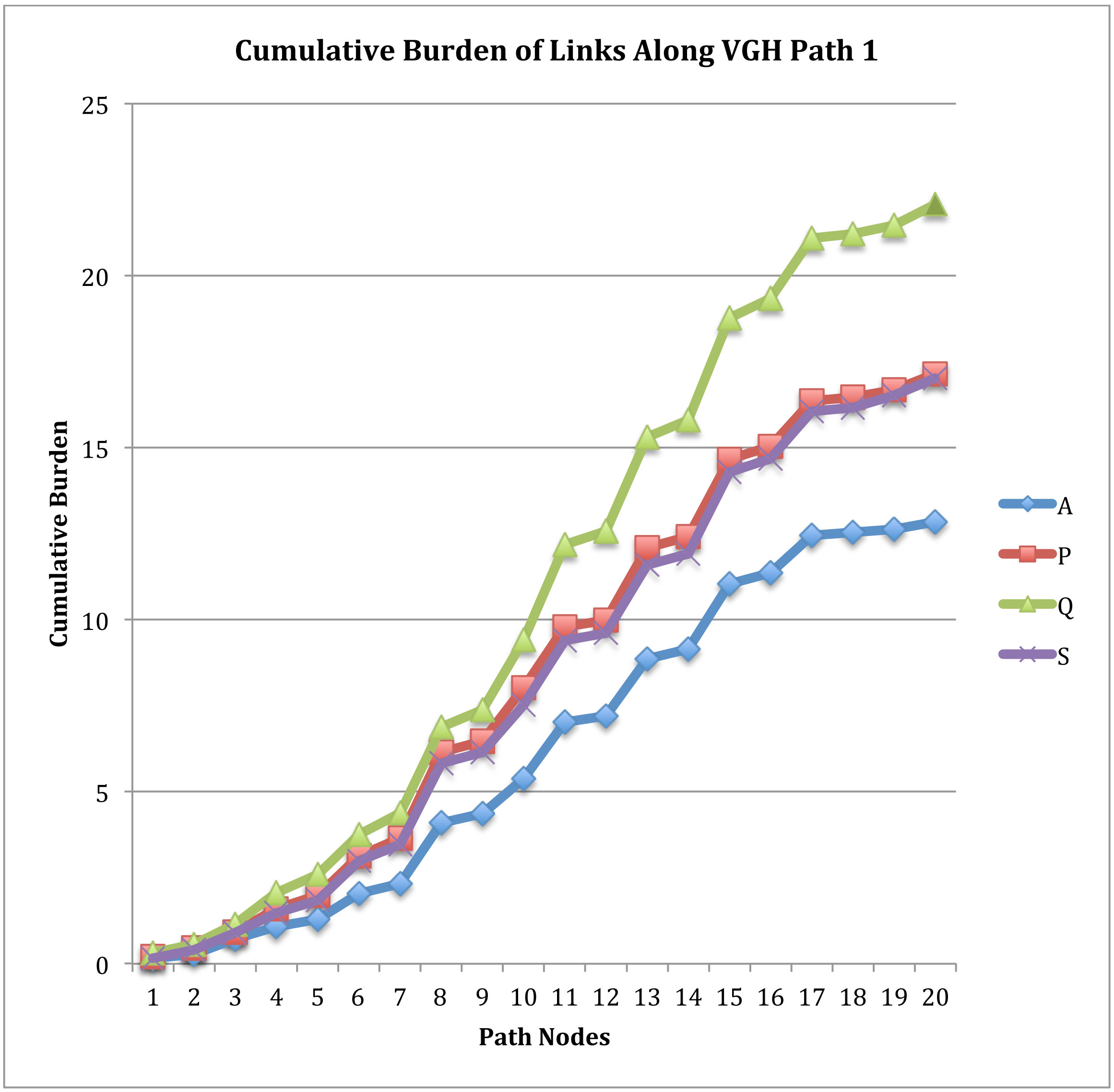

Figure 4.8 Cumulative burden of links along VGH Path #1

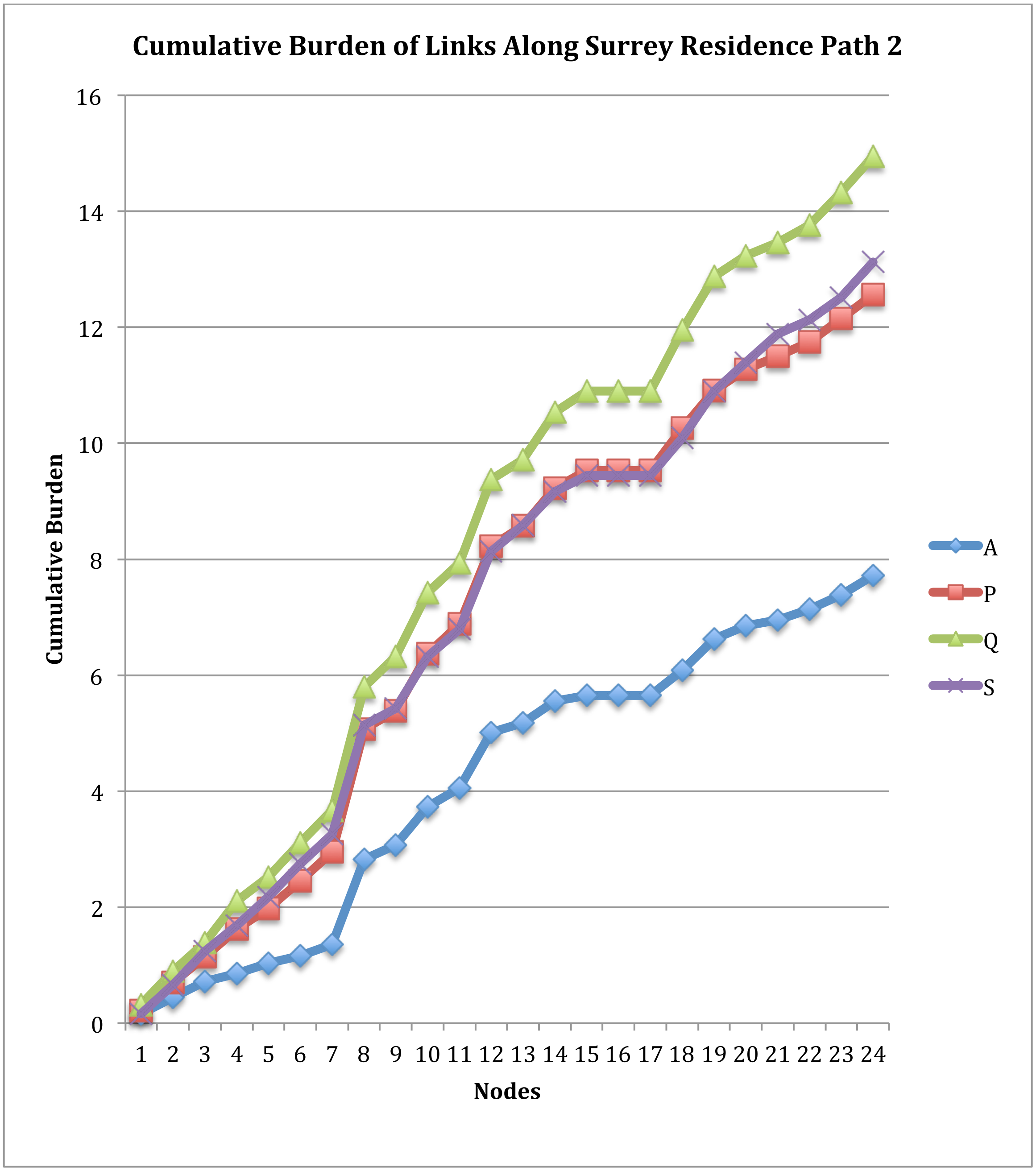

Figure 4.9 Cumulative burden of links along Surrey residence Path #2

In order to compare paths equally, a ratio between the actual distance and the resultant burden can be used giving a standard burden/m value. This ratio indicates the degree to which distance impacts the resulting burden. A number approaching 100 suggests that path conditions are not significant for that Ability profile. In Table, we see that the ratio is higher for the able-bodied group than all others. The paraplegic and scooter groups are usually second although this is not always the case while quadriplegics are always at the bottom. The ratio for the entire path is 65.6.

Table 4.18 Ratio of Distance to Burden for Vancouver CIty Hall Path #1

Path	A	P	Q	S
1	100.0	75.1	50.0	100
2	93.8	55.7	47.0	53.7
3	54.5	34.1	30.6	26.1
4	100.0	26.9	18.0	29.0
5	100.0	51.0	43.6	36.7
6	100.0	27.4	22.1	23.0
7	100.0	39.8	35.1	38.7
8	60.0	41.5	41.5	46.7
9	49.0	37.9	23.0	42.1
10	48.6	32.8	29.1	36.0
11	36.9	23.3	23.3	25.3
12	50.2	35.8	33.4	35.9
13	59.9	28.4	28.4	22.2
14	66.7	38.5	30.6	42.9
15	100.0	32.8	27.9	36.0
16	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0
18	70.6	41.1	28.4	46.2
19	77.1	63.9	45.6	51.9
20	44.4	28.0	28.0	20.5
21	100.0	43.1	43.1	20.5
22	100.0	78.8	62.5	75.1
23	36.7	22.2	16.0	23.6
24	62.7	50.1	34.2	34.3

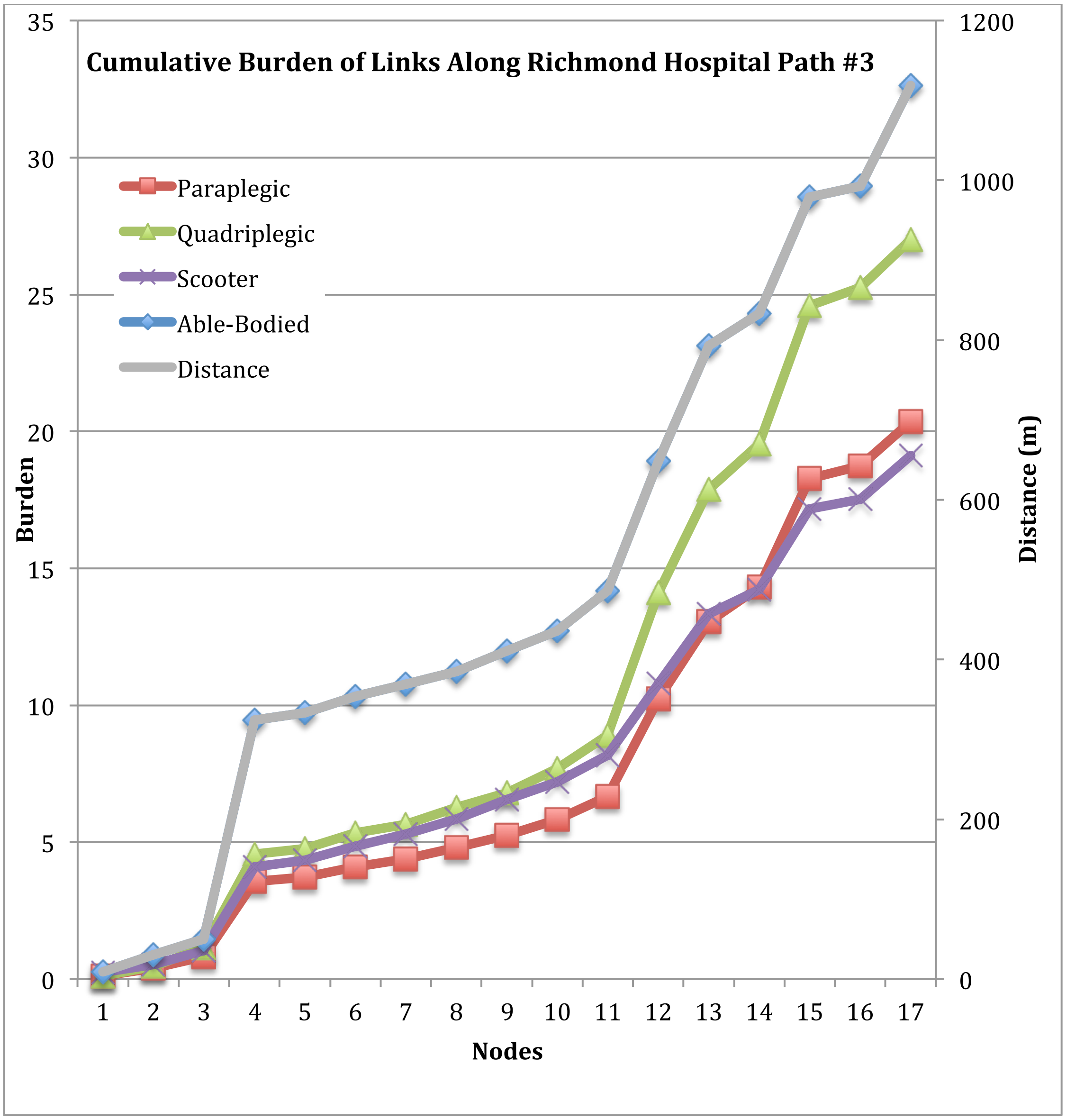

Figure 4.10 Cumulative burden of links along Richmond Hospital Path #3

When examining paths across all of the case study areas, the burden per metre ratio for paraplegics was 1.41 times that of able-bodied population, 1.8 times for quadriplegics, and 1.44 times for the scooter group. If the proposed catchment area has an 800m radius, the equivalent burden would be approximately 9.5 for the able-bodied group, 13.4 for paraplegics, 17.8 for quadriplegics, and 13.7 for those using scooters (calculated as burden/m * 800m). If the able-bodied value is used as the standard, this results in an effective distance of 568m for quadriplegics, 430m for quadriplegics, and 559m for scooter users (calculated as 9.5/559*800 for scooters). That means a paraplegic would be able to travel only 71% as far, a quadriplegic 54% as far, and a scooter 70% as far. This equates to half the area covered for paraplegics and scooters and 29% for quadriplegics.

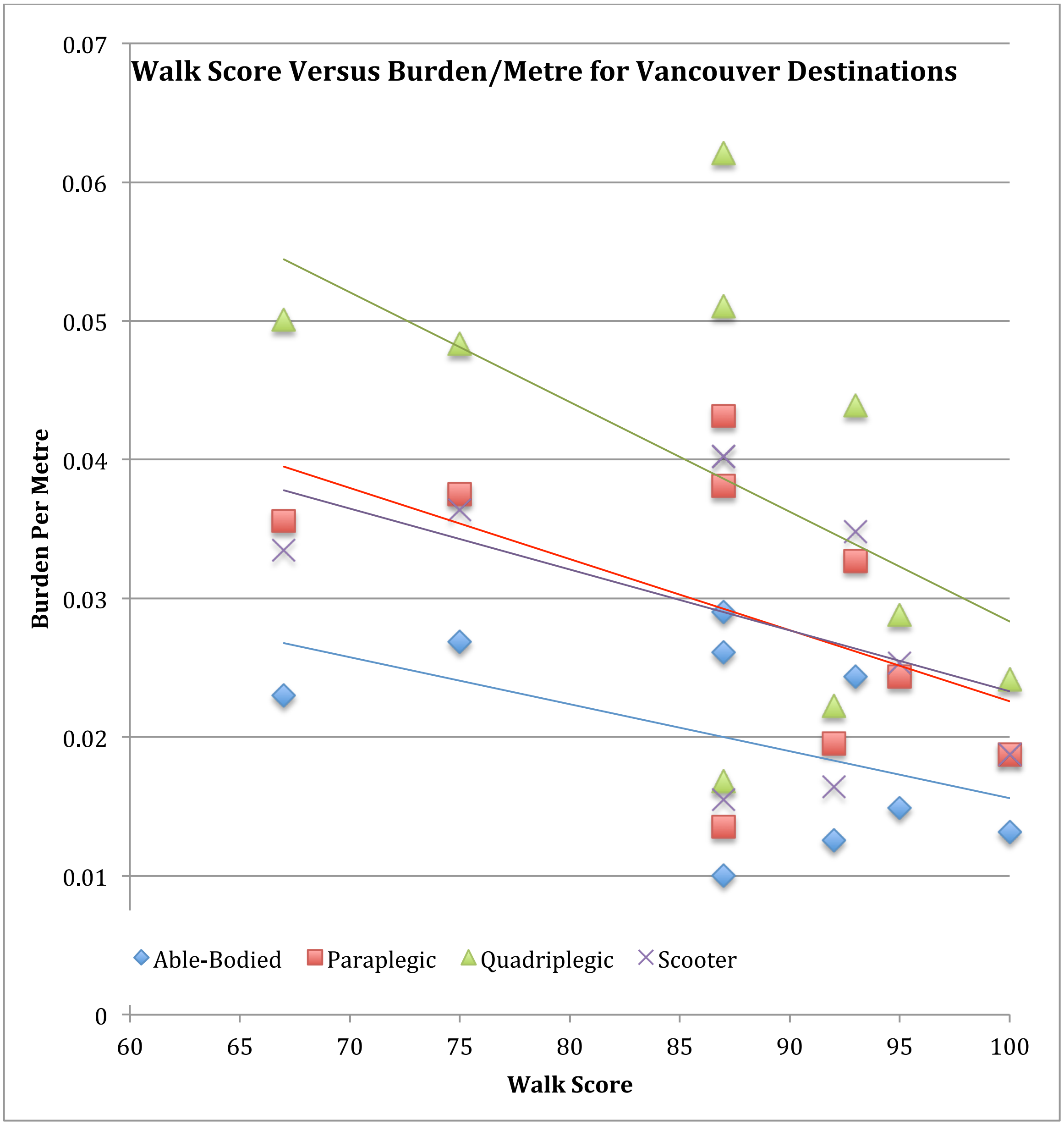

Figure 4.11 Walk Score versus burden/metre for Vancouver destinations

Lastly, a comparison in is made between the Walk Score and alternative measure burden per metre in Figure 4.11. In this chart the correlation between Walk Score and burden per metre appears moderate (a correlation of between -44% to -51% (as Walk Score improves, burden per metre is reduced) but this is based on just 9 data points per Ability Profile group. While the Walk Score suggests some connection to burden, it is clearly not enough on its own.

4.5 Conclusion

The preceding analysis was not intended to be comprehensive for the study areas but to identify accessibility challenges that exist from an absolute and relative perspective. The data suggests that there are important differences in the social topography for PWDs versus their able-bodied counterparts. It also highlights the differences that exist between disability groups. The case study areas assessed provided evidence that the research questions posed need to be examined more carefully and translated into policies and practices that will bridge the apparent gaps.

The final chapter will discuss the implications of these findings, gaps that need to be addressed, and the potential this approach has for urban planning theory and practice.

5 CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS FOR PLANNING

5.1 Conclusions

This research addressed a number of issues related to active mobility networks (AMNs) as they relate to PWDs. Prior to undertaking the case studies, the literature review described what AMNs were, why they are important, and how they unfold. Statistics on the current economic, health, and social status of PWDs suggests that PWDs may not be getting the same benefits as the able-bodied population. A failure to incorporate PWDs needs and preferences into the principles, models, and tools used to design walkable environments is an issue. Emerging transportation planning approaches may offer a more 'embodied approach' through a networked perspective. Moving forward, therefore requires going beyond traditional models of planning and disability to achieve more inclusive transportation networks.

While the prime objective of this study was not to explain why or how this came to be, limited economic resources, reliance on the medical model of disability, and a lack of guiding principles that address a broader swath of societal needs has not resulted in AMNs for everyone. In order to skillfully address this deficiency, a systematic approach is needed that starts with first principles – people. This means building a better understanding of the heterogeneous needs and preferences of PWDs and embedding them into urban planning theory and practice.

The research questions attempt to understand the form and content of accessibility as well as how this relates to the people being impacted. The first question seeks to identify the tangible constraints in the environment as they relate to people with mobility impairments. It suggests that accessibility is a product of conditions that place both absolute and relative challenges on the physical abilities of individuals. From the research, it becomes evident that there are a number of natural and artificial physical barriers that exist that deter PWDs from getting around their own communities. Node and link accessibility are impacted by slope, cross slope, surface quality (ie., is it firm, stable, level, slip-resistant), clear width, presence of obstacles (e.g. stairs, sandwich boards, light poles), presence of hazards (e.g. driveways with limited visual access, protruding branches, unprotected drop-offs). When these conditions are combined over a given distance, the emergence of relative accessibility becomes apparent. The case study areas exhibited hundreds of these accessibility challenges all within close proximity of major transportation hubs. Considering the case study areas represent some of the busiest areas in all of western Canada, the highest standards for access would be expected in these active mobility networks (AMNs). Despite this, a number of environmental constraints remain that fail to meet the needs and preferences of PWDs.

The second question compares the ability profiles of able-bodied people, paraplegics using manual wheelchairs, quadriplegics using manual wheelchairs, and people using scooters against the constraints in a networked view of the environment. These four groups were given typical profiles that could be compared against the environmental constraints in three busy transit areas. The results showed a great deal of inequity in these networks. A majority of links and nodes were scored as difficult or very difficult in the case study. These results suggest that people with disabilities are poorly connected (or in some cases completely disconnected) from the resources they need in their daily lives.

Absolute barriers of links and nodes decreased the reach AMNs had for people with disabilities. When taking the cumulative burden of these links, further limitations in the network become evident. If these links were all overlapped we would start to see a social topography that looked a little like shrunken Swiss cheese. It would be full of holes (inaccessible regions) and would cover less distance once we place limits on how far someone could reasonably travel. The claims of what is walkable are very different than what we find in the walkability literature. This should have a significant impact on how communities are designed and managed.

Environmental conditions placed a greater burden on PWDs. The social topography of paraplegics was better than that for quadriplegics while scooters showed more variability. Networks for all PWDs were smaller than for their able-bodied counterparts and not seamless. The access scores of both nodes and paths were often deemed difficult or very difficult. For these groups, accessing the resources in their communities is compromised resulting in an inequitable situation. Figure 5.1 represents the impact of opportunities available when absolute and relative accessibility are included in the analysis.

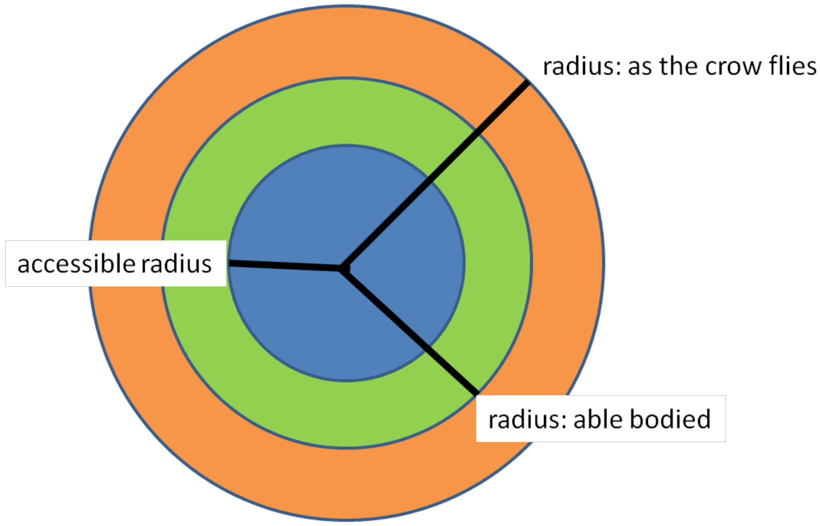

Figure 5.1 Social topography comparison

In particular street crossings, despite engineering standards, result in curb cuts that areto a major barrier or hazard to travel. Natural challenges like slope are more difficult to address but planning decisions can mitigate these problems in some cases. For instance, in order to get from the Broadway station in Vancouver to City Hall, transit users would have to go up a very steep street to get to either the rear or main entrance. In this situation, offering a public entrance on 10th Avenue that borders the north side of the property could reduce some of the impacts of the steep terrain.

A key to the findings is that accessibility is not just an absolute measure as is operationalized in practice. It has two sides to it – an absolute barrier created resulting from an environmental constraint exceeding someone's capabilities and – a relative barrier cause by the cumulative conditions faced in the environment (e.g., distance, slope, surface conditions, etc.). If models are going to use standards like an 800m radius, awareness of the social topography of that area is necessary.

The third question then asks how theory and practice have helped to shape AMNs and their accessibility. The policy and literature review show that existing accessibility standards focus on building access and are based on measures that are not entirely inline with the current ability profiles of PWDs. Emphasized throughout is the fact that this mismatch may be attributable to the use of the average, able-bodied individual as the goal of design. Legislation, Official Plans and other high-level documents pay little attention to the accessibility challenge. When it is addressed, there are no objective metrics from which to evaluate plans.

Existing walkability indices rarely address accessibility and when they do, fail to embody the way in which PWDs experience the environment. A focus on density (and lesser extend diversity and design) does not capture the networked nature of a PWD's needs and preferences. Emerging transportation planning models that consider the network approach need to consider accessibility as discussed in this research. And while there is no silver bullet solution to these challenges, urban planning theory and practice needs to better understand the needs and preferences of people.

5.2 Contributions to Research and Practice

Although descriptive in nature, this study contributes to the existing research in a number of ways. In particular, this research challenges the status quo of using the able-bodied modeling unit. By building on emerging research, the nature of accessibility is expanded beyond simple absolute standards of accessibility towards more objective, measurable interpretations that consider both absolute and relative dimensions of accessibility.

This research also challenges those that create walkability audits to incorporate these accessibility measures into their tools. To begin with, this research shows that accessibility doesn't mean the same thing for every person. People with disabilities (all people, in fact), have different needs and preferences. Meeting those needs in a strategic manner means getting a more detailed picture of the AMN network. The social topography approach helps to situate accessibility into a realistic context that embodies how people move about their communities. Existing audits that only sum the number of times a particular element is found may fail to identify disconnects in the network. For Instance, the Irvine-Minnesota Inventory (Day et al. 2005) asks if there are curb cuts at none, some, many or all intersections provides limited information and doesn't explicitly locate which curb cuts are missing. The social topography model not only gives rich information as to the nature of the curb cut conditions but their location and role in the AMN.

5.3 Limitations

At this stage, the social topography model is merely potential. There are assumptions in the model that need to be more strenuously tested. Much like the majority of walkability indices that exist today, validation of the method and survey tool needs to be conducted.

To begin with, the values derived for the Ability Profiles needs to be addressed. Methods like multi-criteria decision analysis (MCDA) accompanied by real world simulations could go a long way in fine-tuning the ranges of values for path conditions. Using MCDA, groups of people with varying disabilities could be asked to evaluate the relative difficult of certain conditions on their travel choices (as in Table 5.1). Because of the nature of the choices, this could be done in conjunction with an outdoor course that presents a series of challenges with varying path conditions (e.g. areas with slopes 2%, 5%, 8.3%, etc.).

Table 5.1 Link conditions analysis

Factor	Importance	High/Low Measure	Preferences
slope	high	8.3%	5%
cross slope	moderate	2%	1%
width	low	810mm	1200mm
surface	high	firm, level, stable	non-slip
obstacle	moderate	50mm	6mm

Another approach might be to use GPS devices (and possibly heart monitors) to track the travel patterns of individuals and then associate them with existing path conditions. However it is achieved, validated input measures would be a critical first step. Once this is established, the formulae proposed can be adjusted accordingly. The relative factors assigned to the different path conditions may need to be adjusted to more closely fit with each of the Ability Profile groups. In the meantime, study areas that at least use the same factors will produce results that would be comparable to each other. The more closely Ability Profiles match environmental conditions, the better able someone is in finding feasible pathways between themselves and the resources in the community they need to reach. Future iterations can include a transit layer to represent the multi-modal travel options that currently exist.

5.4 Implications for Theory

The key implication for research in the area of active mobility networks is that current interpretations of the environment must be challenged. Building models based on the average, able-bodied individual results in a distorted view of the real world. Applying measures that “average out” across census tracts, for instance, misrepresent the seamless nature of the networked reality that PWDs live in. It is not enough to say that a new development will be within 800m of a school, church, recreation centre, shopping, etc. Consider the following (common) scenario (see Figure 5.2). Imagine a neighbourhood where an individual lives at Node A and is trying to reach Node C. The most direct route is A to E (40m) to C (40m) is 80m apart. However, the access rating for these two links is calculated to be a 3 for this person. The result is a burden of (40/100*3*2 = 2.4) whereas the indirect route from A to B (50m) to C (50m) is 100m long with access ratings of 1 resulting in a burden of (50/100*1*2 = 1). This is a difference of 20m further but a reduction of 1.4 in burden. This scenario occurs where E may be at the top of a localized hill or E is an obstacle like stairs. A path (A to E to C) exists as well as options around (A to B to C or A to D to C).

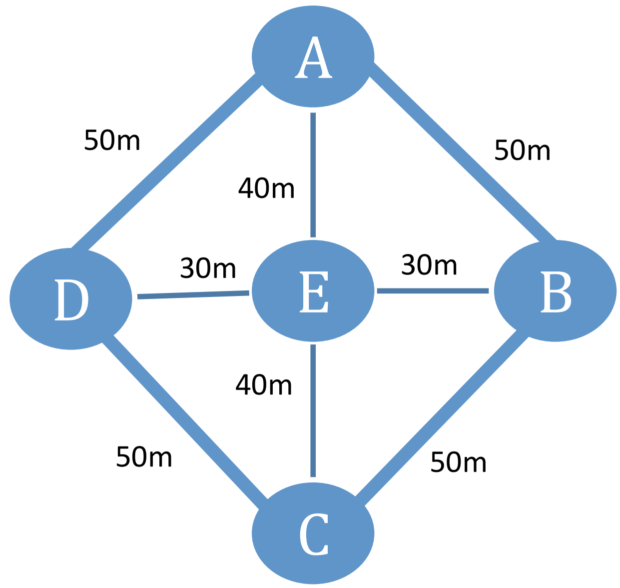

Figure 5.2 Typical neighbourhood scenario

Viewed in isolation, this may not seem to have significant impact. However, when the scenario above is multiplied over a number of routes linking to a number of resources this becomes a complex challenge. Figure 5.3 below depicts a similar situation with the person trying to from home to their target but finding that the link from K to L is disrupted by construction. With that link removed from the network, a burden of 850 (pink line) is replaced with options that have burdens of 1600 (green line) or 1700 (black line). This is an example of a network that is sensitive to disruption and not robust from the perspective of the individual trying to go from home to the designated target.

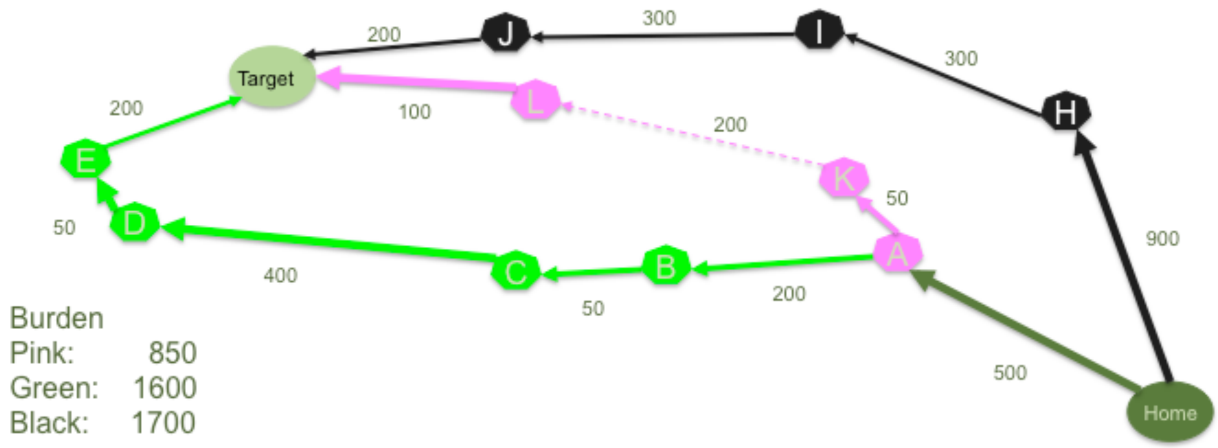

Figure 5.3 Route analysis example

Theoretical models that do not incorporate burden or network measures may miss the potential breakdowns that exist and therefore overestimate the walkability of a neighbourhood. As more and more nodes and links are added to the network, the complexity of the analysis increases and compromises the conclusions that can be made. In particular, weak design parameters overestimate the density calculations. A simple average of the number of nodes within a geographical boundary does not consider the needs of nearly 20% of the target population.

A promising interdisciplinary approach would be to leverage social network analysis in a similar vein used in transportation analysis. Measures such as network centrality based on accessibility adjusted network measures may help in locating key services in the community. For instance, identifying scenarios such as those found in Figure 5.3 may make it easier for planners and the public to understand AMNs.

Ultimately, urban planning research needs to acknowledge the heterogeneous public that gets plugged into their models and how that affects their conclusions. Awareness is the first step but acknowledging the nuances of accessibility and inclusion, in particular absolute versus relative access must follow. Once this is achieved, urban planning theory can better support urban planning practice and help promote more accessible and inclusive communities.

5.5 Implications for Planners

As with research, urban planners can benefit from the social topography model by gaining a better understanding of the broader accessibility and inclusion system. The current focus on the nodes (building standards) in the system is a good start but an understanding of how they fit into the interdependent network of sidewalks, paths, and transit is necessary. This includes understanding the implications of both absolute and relative access within a seamless network.

From this research, urban planners may be able to start to calculate values for the overall social topography of a proposed development before shovels go into the ground. This model also provides a common language and metrics that can be used when engaging public input. This will mean that decisions can be more objective, measurable, and transparent.

Most importantly, the model is intended to give urban planners with the tools to make more strategic decisions about what to do with their limited budgets. By being able to target paths and nodes that are central to the AMN, they will achieve greater return on their investment. Providing public information about closures or construction can also assist in their role in awareness.

5.6 Implications for Communities

The social topography model offers objective and measureable information about access and inclusion that can be of great benefit to the public. Businesses and not-for-profit agencies get detailed information that will allow them to fill in gaps in the network that governments cannot provide (or are not willing to provide on their own like a fresh food delivery service to an independent living centre). Advocacy groups can use social topography measures to ensure governments live up to their responsibilities to serve all of their publics.

Combined with existing and emerging technologies, information systems like personalized navigation systems teaming up with smart city technologies that can provide real-time information will make active travel more likely. In fact, information is a critical first step. For users of AMNs, simply knowing what their options are might be enough to get them active. The implications of this are spelled out in the literature review regarding the economic, health, social, and environmental benefits accrued.

5.7 Recommendations

While the future potential is great, there are challenges with regards to the current state of the model as stated above. It is recommended that steps to validate the proposed model, perhaps in conjunction with existing models and tools, be the next step. As well, the formulae and analytical tools suggested need to be further flushed out. These steps need to consider the current and future state of data management. The granularity of data demanded needs to be economically feasible to actually collect or alternative methods like crowdsourcing (i.e. including public participation) devised to fill in the blanks. Researchers in the field and planners on the ground need to build a greater awareness of the implications of their decisions on a growing disability population. This means understanding their Ability Profiles, the environmental constraints that result from urban design and management decisions. Government needs to provide information and promote collaboration with private organizations and individuals to develop feasible solutions. Finally, the public, especially PWDs, must demand that their needs and preferences are addressed in a way that will allow them to be active members of their community in a sustainable way.

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APPENDIX A ANTHROPOMETRIC MEASUREMENTS

Source: Kozey, D.B, & Appl, JW. (1999) Structural anthropometric measurements for wheelchair mobile adults. *Appl Ergonom*,30: 385-390.

MALES

dimension (in mm)	**SD**	**5th percentile**	**mean**	**95th percentile**
seated stature	70	734	848	963
eye height	67	625	735	845
shoulder height	63	468	572	676
forearm height	62	108	210	312
knee height	49	118	199	280
toe height	71	- 109	- 226	- 343
horizontal reach height	67	496	607	717
maximal reach height	104	1072	1243	1415
elbow-grip depth	27	444	488	532
arm length	35	573	631	689
maximal reach depth	45	779	853	926
trunk depth	25	198	240	281
shoulder width bideltoid	35	452	510	568
schoulder width acromion	26	354	396	439
elbow width	57	533	626	720
overall length wheelchair	64	1022	1127	1216
seat pan height	60	362	461	560

All dimensions are with respect to the seat pan

FEMALES

dimension (in mm)	**SD**	**5th percentile**	**mean**	**95th percentile**
seated stature	64	647	752	857
eye height	60	546	645	744
shoulder height	53	423	510	597
forearm height	46	105	181	257
knee height	52	86	172	258
toe height	64	- 94	- 199	- 304
horizontal reach height	79	372	502	632
maximal reach height	87	947	1090	1234
elbow-grip depth	24	411	450	490

arm length	33	526	581	635
maximal reach depth	43	697	768	839
trunk depth	23	143	182	220
shoulder width bideltoid	53	383	469	556
schoulder width acromion	39	291	355	418
elbow width	78	465	593	721
overall length wheelchair	87	920	1063	1206
seat pan height	55	383	473	563

All dimensions are with respect to the seat pan

APPENDIX B UNIVERSAL DESIGN PRINCIPLES

PRINCIPLE ONE: Equitable Use
The design is useful and marketable to people with diverse abilities.

Guidelines:
1a. Provide the same means of use for all users: identical whenever possible; equivalent when not.
1b. Avoid segregating or stigmatizing any users.
1c. Provisions for privacy, security, and safety should be equally available to all users.
1d. Make the design appealing to all users.

PRINCIPLE TWO: Flexibility in Use
The design accommodates a wide range of individual preferences and abilities.

Guidelines:
2a. Provide choice in methods of use.
2b. Accommodate right- or left-handed access and use.
2c. Facilitate the user's accuracy and precision.
2d. Provide adaptability to the user's pace.

PRINCIPLE THREE: Simple and Intuitive Use
Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

Guidelines:
3a. Eliminate unnecessary complexity.
3b. Be consistent with user expectations and intuition.
3c. Accommodate a wide range of literacy and language skills.
3d. Arrange information consistent with its importance.
3e. Provide effective prompting and feedback during and after task completion.

PRINCIPLE FOUR: Perceptible Information
The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

Guidelines:
4a. Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information.
4b. Provide adequate contrast between essential information and its surroundings.
4c. Maximize "legibility" of essential information.
4d. Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions).

4e. Provide compatibility with a variety of techniques or devices used by people with sensory limitations.

PRINCIPLE FIVE: Tolerance for Error
The design minimizes hazards and the adverse consequences of accidental or unintended actions.

Guidelines:
5a. Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded.
5b. Provide warnings of hazards and errors.
5c. Provide fail safe features.
5d. Discourage unconscious action in tasks that require vigilance.

PRINCIPLE SIX: Low Physical Effort
The design can be used efficiently and comfortably and with a minimum of fatigue.

Guidelines:
6a. Allow user to maintain a neutral body position.
6b. Use reasonable operating forces.
6c. Minimize repetitive actions.
6d. Minimize sustained physical effort.

PRINCIPLE SEVEN: Size and Space for Approach and Use
Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

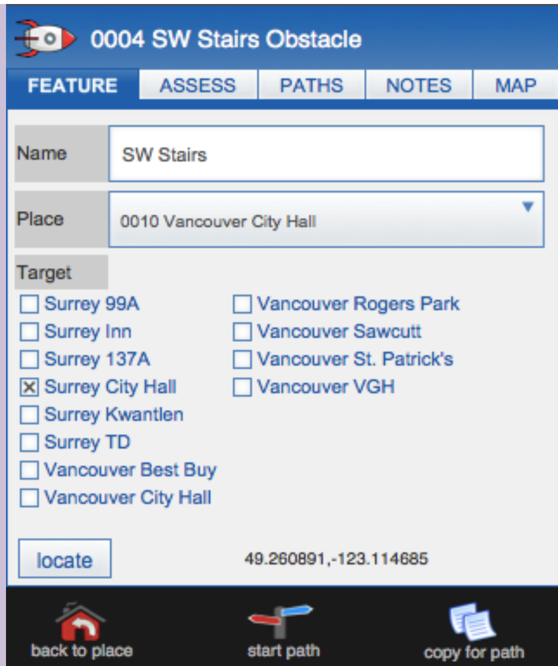
Guidelines:
7a. Provide a clear line of sight to important elements for any seated or standing user.
7b. Make reach to all components comfortable for any seated or standing user.
7c. Accommodate variations in hand and grip size.
7d. Provide adequate space for the use of assistive devices or personal assistance.

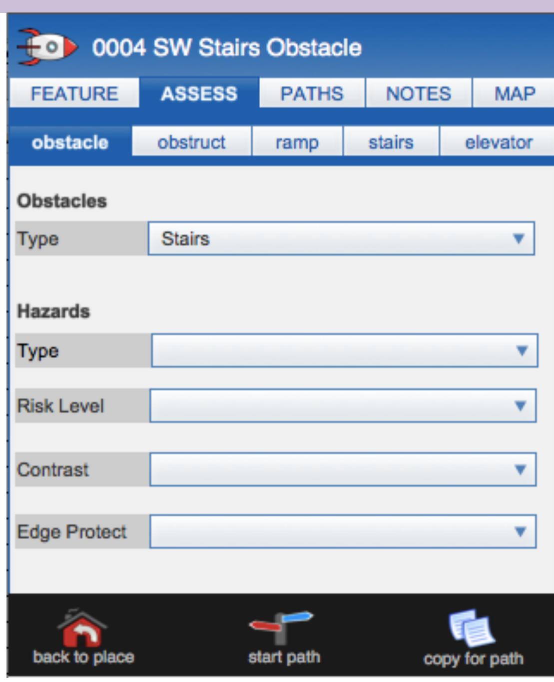
These are directly taken from the Center of Universal Design website at North Carolina State University.

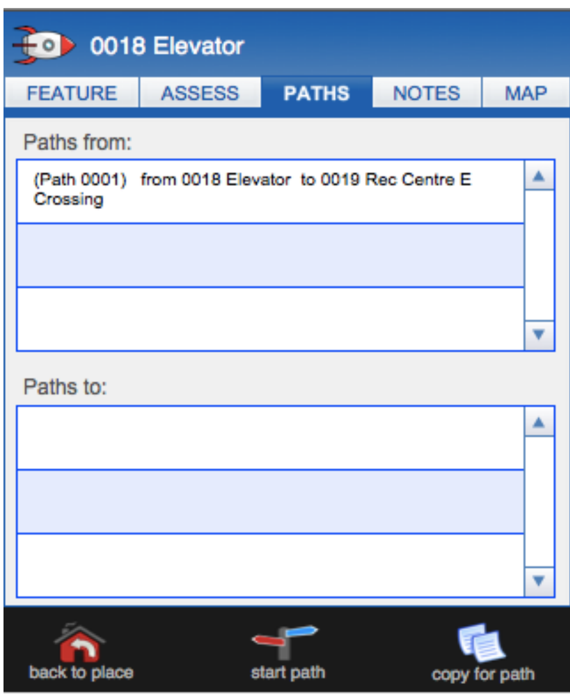
Bettye Rose Connell, Mike Jones, Ron Mace, Jim Mueller, Abir Mullick, Elaine Ostroff, Jon Sanford, Ed Steinfeld, Molly Story, and Gregg Vanderheiden (1997)

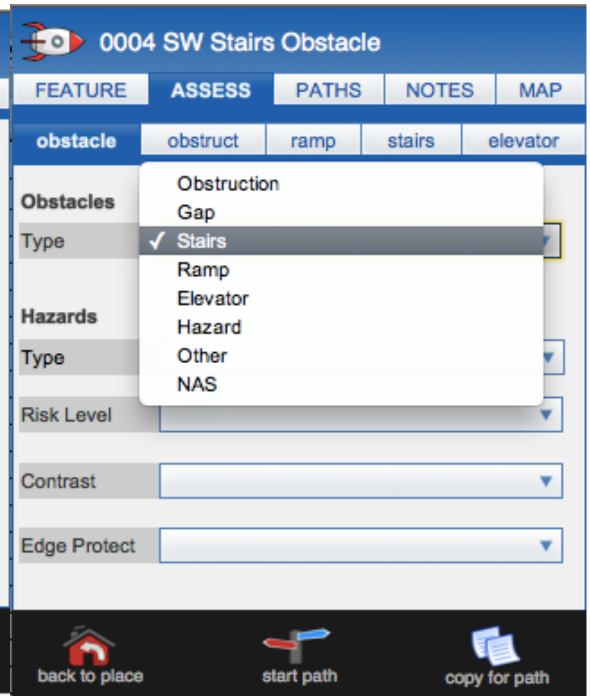
APPENDIX C SOCIAL TOPOGRAPHY ASSESSMENT TOOL (AUDIT)

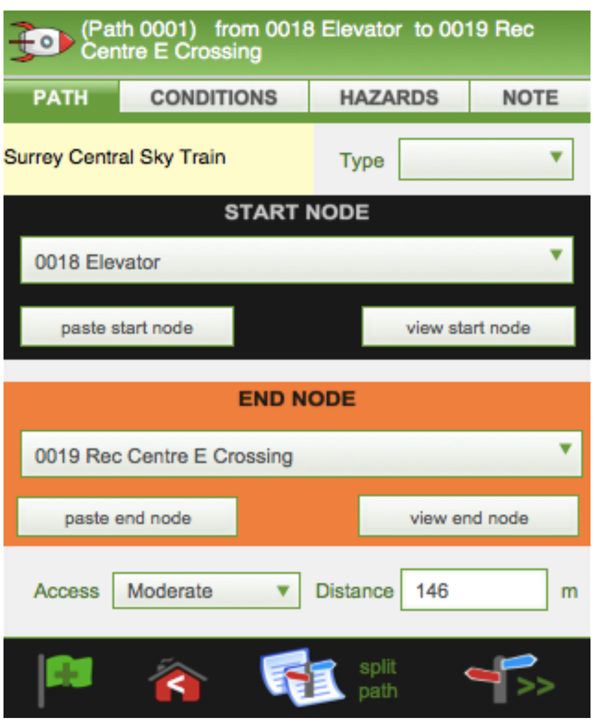
Social Topography Assessment Tool – Screenshots (FileMaker Pro and Go database)

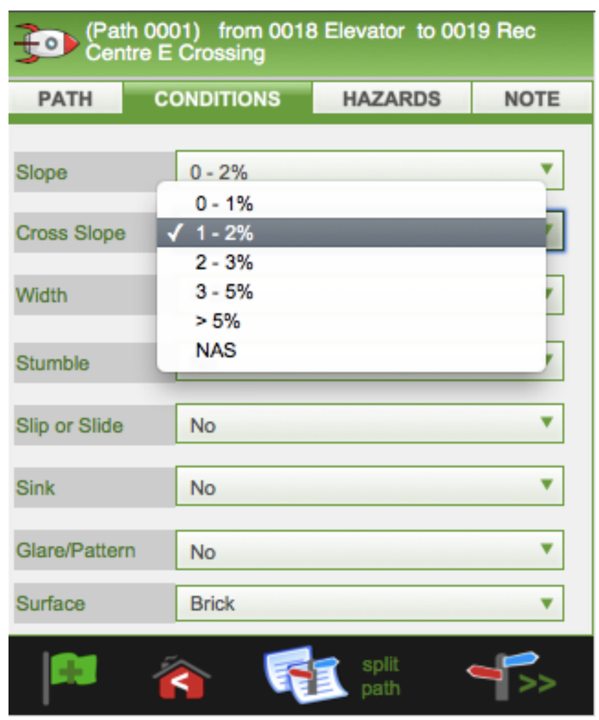





0018 Elevator
FEATURE
ASSESS
PATHS
NOTES
MAP
Paths from:
(Path 0001) from 0018 Elevator to 0019 Rec Centre E Crossing
Paths to:
back to place
start path
copy for path


0004 SW Stairs Obstacle
FEATURE
ASSESS
PATHS
NOTES
MAP
obstacle
obstruct
ramp
stairs
elevator
Obstacles
Type
Hazards
Type
Risk Level
Contrast
Edge Protect
Obstruction
Gap
Stairs
Ramp
Elevator
Hazard
Other
NAS
back to place
start path
copy for path


(Path 0001) from 0018 Elevator to 0019 Rec Centre E Crossing
PATH
CONDITIONS
HAZARDS
NOTE
Surrey Central Sky Train
Type
START NODE
0018 Elevator
paste start node
view start node
END NODE
0019 Rec Centre E Crossing
paste end node
view end node
Access
Moderate
Distance
146
m
split path


(Path 0001) from 0018 Elevator to 0019 Rec Centre E Crossing
PATH
CONDITIONS
HAZARDS
NOTE
Slope
0 - 2%
Cross Slope
0 - 1%
1 - 2%
2 - 3%
3 - 5%
> 5%
NAS
Width
Stumble
Slip or Slide
No
Sink
No
Glare/Pattern
No
Surface
Brick
split path

APPENDIX D CASE STUDY DATA

Vancouver City Hall Path 1

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_N	a_P	β	a_N	a_P	d
1	2	0.160	1	1	0.213	1	2	0.320	1	4	0.160	1	1	16
2	3	0.288	1	1	0.485	2	3	0.575	2	3	0.503	2	4	27
3	4	0.275	2	1	0.440	3	2	0.490	3	2	0.575	4	3	15
4	5	0.130	1	1	0.484	3	3	0.722	4	4	0.449	3	3	13
5	6	0.180	1	1	0.353	2	2	0.413	2	2	0.490	3	3	18
6	7	0.130	1	1	0.475	3	3	0.588	3	4	0.566	4	3	13
7	8	0.200	1	1	0.503	3	2	0.570	3	2	0.517	3	3	20
8	9	1.467	1	3	2.120	2	4	2.120	2	4	1.885	2	3	88
9	10	0.245	2	1	0.317	2	2	0.522	3	4	0.285	2	3	12
10	11	0.658	2	3	0.975	3	4	1.100	4	4	0.890	3	3	32
11	12	0.325	2	3	0.514	3	4	0.514	3	4	0.474	3	3	12
12	13	0.957	2	3	1.341	2	4	1.437	2	4	1.338	3	3	48
13	14	0.167	1	3	0.352	2	4	0.352	2	4	0.450	3	3	10
14	15	0.375	2	1	0.650	3	2	0.817	3	4	0.583	3	3	25
15	16	0.100	1	1	0.305	2	3	0.358	2	4	0.278	2	3	10
16	17	0.000	1	1	0.000	1	2	0.000	1	4	0.000	1	3	4
17	18	0.000	1	1	0.000	1	2	0.000	1	4	0.000	1	3	13
18	19	0.425	2	1	0.730	3	2	1.055	4	4	0.650	3	3	30
19	20	0.545	2	1	0.657	2	2	0.922	3	2	0.810	3	3	42
20	21	0.225	2	1	0.357	3	2	0.357	3	2	0.488	4	3	10
21	22	0.100	1	1	0.232	2	2	0.232	2	2	0.488	4	3	10
22	23	0.190	1	1	0.241	1	2	0.304	1	2	0.253	1	3	19
23	24	0.245	2	2	0.406	3	3	0.561	4	4	0.382	3	3	9
24	25	0.335	2	1	0.419	2	2	0.614	3	3	0.613	4	3	21
		7.722			12.569			14.943			13.127			517

β –path segment burden a_N – access score for node a_P – access score for path d - distance

Vancouver City Hospital Path 2

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
1	2	0.160	1	1	0.213	1	2	0.32	1	4	0.16	1	1	16
2	26	0.110	1	1	0.242	2	2	0.242	2	2	0.25	2	3	11
26	39	0.445	2	1	0.53	2	2	0.762	3	2	0.552	2	3	32
39	57	0.544	1	2	0.737	2	2	1.009	2	2	0.805	2	4	51
57	58	1.335	2	1	1.541	3	2	2.186	3	2	1.746	4	3	121
58	59	0.190	1	1	0.328	2	2	0.391	2	2	0.465	3	3	19
59	60	1.370	1	1	1.586	2	2	2.317	2	2	1.678	2	3	137
60	61	0.203	1	2	0.378	2	3	0.442	2	3	0.641	4	4	19
61	62	0.265	2	1	0.302	2	2	0.474	3	2	0.312	2	3	14
62	63	0.885	2	1	1.088	2	2	1.466	3	2	1.263	3	3	76
63	64	0.490	3	1	0.631	4	2	0.759	4	2	0.647	4	3	24
64	65	0.365	2	1	0.429	2	2	0.634	3	2	0.445	2	3	24
65	66	0.520	3	1	0.861	4	3	0.879	4	3	0.861	4	4	27
66	67	0.232	2	2	0.43	3	2	0.622	4	4	0.535	4	4	10
67	68	0.223	2	2	0.395	3	3	0.418	3	4	0.501	4	3	7
68	69	0.133	1	3	0.306	2	4	0.306	2	4	0.285	2	3	8
69	70	0.420	1	1	0.573	2	2	0.657	2	2	0.601	2	3	42
70	71	0.160	1	2	0.335	2	2	0.335	2	2	0.345	2	3	15
71	72	1.666	2	2	1.973	3	3	2.426	3	3	2.188	4	4	136
72	73	0.210	1	1	0.461	2	2	0.726	3	4	0.53	3	3	21
73	74	0.140	1	1	0.302	2	2	0.349	2	2	0.437	3	3	14
74	56	1.095	2	1	1.802	3	2	2.574	4	3	1.543	3	3	97
		11.16			15.44			20.29			16.79			921

Vancouver City Hospital Path 3

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
1	2	0.160	1	1	0.213	1	2	0.32	1	4	0.16	1	1	16
2	26	0.110	1	1	0.139	1	2	0.176	1	2	0.147	1	3	11
26	27	0.820	1	1	1.109	2	2	1.109	2	2	1.109	2	2	82
27	42	0.456	2	2	0.662	2	2	0.994	3	4	0.58	2	3	31
42	43	0.295	2	1	0.465	3	2	0.522	3	2	0.477	3	3	17
43	75	0.830	1	1	1.453	2	2	2.006	2	4	1.357	3	3	83
75	76	0.195	2	1	0.2	2	2	0.214	2	2	0.204	2	3	7
76	77	0.780	1	1	1.113	2	2	1.373	2	2	1.165	2	3	78
77	78	0.305	2	1	0.478	3	2	0.663	4	2	0.49	3	3	18
78	79	0.655	2	1	0.973	2	2	1.451	3	4	0.957	3	3	53
79	80	0.410	1	1	0.437	1	2	0.656	1	2	0.492	1	4	41
80	81	0.800	1	1	1.227	1	2	1.76	1	4	0.96	1	2	80
81	82	0.477	3	2	0.692	4	3	0.749	4	4	0.636	4	2	17
82	83	2.480	1	1	2.605	2	1	2.605	2	1	2.895	3	2	248
83	84	0.330	1	1	0.543	2	2	0.653	2	2	0.69	3	3	33
84	56	0.885	2	1	1.466	3	2	2.098	4	3	1.263	3	3	76
		9.987			13.776			17.349			13.581			891

Vancouver Millyard Path 1

From	To	A			P			Q			S			
		β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
1	2	0.160	1	1	0.213	1	2	0.32	1	4	0.16	1	1	16
2	26	0.110	1	1	0.117	1	2	0.117	1	2	0.125	1	3	11
26	85	0.270	1	1	0.539	2	2	0.719	2	4	0.449	2	2	27
85	86	0.355	2	1	0.572	3	2	0.896	4	4	0.651	4	4	23
86	87	0.323	2	3	0.396	2	4	0.521	3	4	0.617	4	4	11
87	88	0.853	2	3	1.286	3	4	1.411	4	4	1.314	3	4	42
88	89	0.305	2	1	0.413	2	2	0.658	3	4	0.365	2	3	18
89	90	1.333	1	3	1.938	2	4	1.938	2	4	1.85	3	3	80
90	91	0.295	2	1	0.34	2	2	0.522	3	2	0.477	3	3	17
91	92	0.465	2	1	0.737	2	3	1.157	3	4	0.646	2	3	34
92	93	1.145	2	1	1.882	3	2	2.687	4	4	1.61	3	3	102
93	94	0.205	2	1	0.367	3	3	0.535	4	4	0.498	4	3	8
94	95	1.310	1	1	1.397	1	2	2.221	2	2	1.61	2	3	131
95	96	0.340	1	1	0.544	1	2	0.896	2	4	0.578	2	3	34
96	97	0.325	2	1	0.463	3	2	0.655	4	2	0.352	2	3	20
97	98	0.645	2	1	0.784	2	2	1.082	3	2	1.068	4	3	52
98	99	0.650	3	2	0.955	4	3	1.055	4	4	0.875	4	3	30
99	100	0.710	3	1	0.958	4	2	1.111	4	2	0.988	4	3	46
100	101	0.205	2	1	0.378	3	2	0.556	4	4	0.482	4	3	8
101	102	1.260	1	1	1.469	2	2	2.141	2	2	1.678	3	3	126
102	103	0.140	1	1	0.399	3	2	0.599	4	2	0.534	4	3	14
103	104	0.505	2	1	0.983	4	2	1.236	4	3	0.882	4	3	38
104	105	0.360	3	1	0.536	4	3	0.595	4	4	0.544	4	3	11
105	106	0.335	2	1	0.586	3	2	0.726	3	3	0.655	4	3	21
106	107	0.245	2	1	0.426	3	3	0.615	4	4	0.559	4	3	12
107	108	0.405	2	1	0.605	3	2	0.823	4	2	0.748	4	3	28
108	109	0.245	2	2	0.454	3	3	0.639	4	4	0.525	4	3	9

	13.499		19.739	26.432	20.839	969

Vancouver Millyard Path 2

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
1	2	0.160	1	1	0.213	1	2	0.32	1	4	0.16	1	1	16
2	26	0.110	1	1	0.117	1	2	0.117	1	2	0.125	1	3	11
26	85	0.270	1	1	0.539	2	2	0.719	2	4	0.449	2	2	27
85	110	0.455	2	1	0.58	3	1	0.881	4	2	0.727	4	2	33
110	111	1.805	2	1	2.253	2	2	2.938	3	2	2.49	3	3	168
111	112	0.405	2	1	0.642	3	2	1.01	4	4	0.567	3	3	28
112	113	0.070	1	1	0.2	2	2	0.223	2	2	0.204	2	3	7
113	114	0.480	1	1	0.637	2	2	0.797	2	2	0.794	3	3	48
114	115	0.285	2	1	0.381	2	2	0.613	3	4	0.463	3	3	16
115	116	0.658	2	3	0.85	2	4	0.975	3	4	0.89	3	3	32
116	117	0.185	2	1	0.209	2	2	0.374	3	4	0.193	2	3	6
117	118	0.712	2	2	0.976	2	3	1.247	3	4	0.858	2	3	44
118	119	0.305	2	1	0.317	2	2	0.538	3	2	0.454	3	3	18
119	95	1.250	1	3	1.825	2	4	1.825	2	4	1.75	3	3	75
95	120	0.190	1	1	0.241	1	2	0.429	2	2	0.378	2	3	19
120	121	1.655	2	1	1.882	3	2	2.823	4	2	1.859	2	3	153
121	122	0.295	2	1	0.34	2	2	0.522	3	2	0.602	4	3	17
122	123	0.745	2	1	0.91	2	2	1.242	3	2	1.202	4	3	62
123	124	0.375	2	1	0.567	3	2	0.65	3	2	0.583	3	3	25
124	125	0.317	2	2	0.562	3	2	0.807	4	4	0.639	4	3	18
125	126	0.120	1	1	0.426	3	3	0.615	4	4	0.434	3	3	12
126	105	0.415	2	1	0.617	3	2	0.714	3	2	0.762	4	3	29
105	106	0.335	2	1	0.544	3	2	0.684	3	3	0.613	4	3	21
106	107	0.245	2	1	0.426	3	3	0.615	4	4	0.559	4	3	12
107	108	0.405	2	1	0.605	3	2	0.823	4	2	0.748	4	3	28

108	109	0.245	2	2	0.454	3	3	0.639	4	4	0.525	4	3	9
		12.492			17.313			23.14			19.029			934

Vancouver Millyard Path 3

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
1	2	0.160	1	1	0.213	1	2	0.32	1	4	0.16	1	1	16
2	26	0.110	1	1	0.117	1	2	0.117	1	2	0.125	1	3	11
26	85	0.270	1	1	0.539	2	2	0.719	2	2	0.449	2	3	27
85	86	0.455	2	1	0.58	3	2	0.881	4	2	0.727	4	3	23
86	87	1.805	2	1	2.253	2	2	2.938	3	2	2.49	3	3	11
87	88	0.405	2	1	0.642	3	2	1.01	4	2	0.567	3	3	42
88	127	0.070	1	1	0.2	2	2	0.223	2	2	0.204	2	3	37
127	114	0.480	1	1	0.637	2	2	0.797	2	4	0.794	3	3	168
114	128	0.285	2	1	0.381	2	2	0.613	3	2	0.463	3	3	23
128	129	0.658	2	1	0.85	2	2	0.975	3	2	0.89	3	3	17
129	130	0.185	2	1	0.209	2	2	0.374	3	2	0.193	2	3	155
130	131	0.712	2	3	0.976	2	4	1.247	3	4	0.858	2	3	35
131	132	0.305	2	1	0.317	2	2	0.538	3	2	0.454	3	3	10
132	133	1.250	1	2	1.825	2	3	1.825	2	4	1.75	3	3	34
133	134	0.190	1	1	0.241	1	2	0.429	2	2	0.378	2	3	17
134	121	1.655	2	3	1.882	3	4	2.823	4	4	1.859	2	4	75
121	122	0.295	2	1	0.34	2	2	0.522	3	2	0.602	4	3	17
122	123	0.745	2	1	0.91	2	2	1.242	3	2	1.202	4	3	62
123	124	0.375	2	1	0.567	3	2	0.65	3	2	0.583	3	3	25
124	125	0.317	2	2	0.562	3	2	0.807	4	4	0.639	4	3	18
125	126	0.120	1	1	0.426	3	3	0.615	4	4	0.434	3	3	12
126	105	0.415	2	1	0.617	3	2	0.714	3	2	0.762	4	3	29
105	106	0.335	2	1	0.544	3	2	0.684	3	3	0.613	4	3	21
106	107	0.245	2	1	0.426	3	3	0.615	4	4	0.559	4	3	12

107	108	0.405	2	1	0.605	3	2	0.823	4	2	0.748	4	3	28
108	109	0.245	2	2	0.454	3	3	0.639	4	4	0.525	4	3	9
		12.492			17.313			23.14			19.029			934

Surrey 99A Residence Path 1														
		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
200	201	1.650	1	1	2.200	1	2	3.630	1	3	1.775	2	1	165
201	202	0.360	2	2	0.374	2	1	0.617	3	2	0.374	2	1	22
202	203	0.685	2	1	0.909	2	3	1.333	3	4	1.071	3	3	56
203	204	0.375	2	1	0.375	2	1	0.633	3	2	0.500	3	1	25
204	205	0.635	2	1	0.771	2	2	1.066	3	2	0.964	3	4	51
205	206	0.100	1	1	0.245	2	2	0.278	2	2	0.377	3	2	10
206	207	2.240	1	1	4.331	1	2	6.696	2	4	3.261	2	4	224
207	208	0.434	2	2	0.637	3	2	0.858	4	2	0.637	3	2	29
208	209	0.445	2	1	0.570	3	1	0.866	4	2	0.570	3	1	32
209	210	1.760	1	1	2.824	2	2	3.997	2	4	2.362	3	2	176
210	211	0.600	1	2	0.965	2	3	1.115	2	4	0.970	3	2	45
211	212	0.168	1	2	0.514	3	3	0.482	3	4	0.506	3	4	12
212	213	1.010	1	1	1.741	2	2	2.414	2	4	1.597	3	3	101
213	214	0.389	3	3	0.588	4	4	0.540	4	4	0.485	3	4	8
214	215	1.125	4	1	1.275	4	2	1.525	4	2	1.325	4	2	75
215	216	0.285	2	2	0.295	2	1	0.500	3	2	0.420	3	1	15
216	217	0.865	2	1	0.865	2	1	1.385	3	2	1.039	3	2	74
217	218	0.295	2	1	0.295	2	1	0.511	3	2	0.420	3	1	17
218	219	0.418	2	2	0.565	2	4	0.807	3	4	0.543	3	2	22
219	220	0.594	2	4	1.038	2	4	1.607	3	4	0.916	3	4	37
220	221	0.576	1	2	0.900	1	2	1.260	1	4	0.720	1	2	54

		15.009			22.276			32.120			20.832			1250
Surrey 99A Residence Path 2														
		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
200	201	0.160	1	1	0.213	1	2	0.320	1	3	0.160	1	1	165
201	202	0.288	1	2	0.485	2	1	0.575	2	2	0.503	2	1	22
202	203	0.275	2	1	0.440	3	3	0.490	3	4	0.575	4	3	56
203	222	0.130	1	1	0.484	3	2	0.722	4	4	0.449	3	2	18
222	223	0.180	1	2	0.353	2	3	0.413	2	4	0.490	3	3	12
223	224	0.130	1	1	0.475	3	2	0.588	3	4	0.566	4	3	51
224	225	0.200	1	2	0.503	3	3	0.570	3	4	0.517	3	4	62
225	226	1.467	1	1	2.120	2	1	2.120	2	2	1.885	2	1	13
226	227	0.245	2	1	0.317	2	1	0.522	3	2	0.285	2	1	13
227	228	0.658	2	1	0.975	3	2	1.100	4	4	0.890	3	2	149
228	229	0.325	2	1	0.514	3	2	0.514	3	4	0.474	3	4	181
229	230	0.957	2	1	1.341	2	2	1.437	2	4	1.338	3	2	16
230	231	0.167	1	2	0.352	2	3	0.352	2	4	0.450	3	4	83
231	232	0.375	2	1	0.650	3	2	0.817	3	3	0.583	3	2	68
232	233	0.100	1	2	0.305	2	1	0.358	2	2	0.278	2	1	19
233	234	0.000	1	1	0.000	1	1	0.000	1	2	0.000	1	1	19
234	235	0.000	1	1	0.000	1	2	0.000	1	2	0.000	1	3	139
235	236	0.425	2	3	0.730	3	4	1.055	4	4	0.650	3	4	13
236	237	0.545	2	4	0.657	2	4	0.922	3	4	0.810	3	4	298
237	238	0.225	2	1	0.357	3	2	0.357	3	4	0.488	4	3	96
238	239	0.100	1	1	0.232	2	2	0.232	2	4	0.488	4	2	15
239	240	0.190	1	1	0.241	1	2	0.304	1	2	0.253	1	3	95
240	241	0.245	2	2	0.406	3	2	0.561	4	2	0.382	3	2	14
241	221	0.335	2	2	0.419	2	2	0.614	3	4	0.613	4	1	249

		7.722			12.569			14.942			13.128			1866
Surrey 99A Residence Path 3														
		A			**P**			**Q**			**S**			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
200	242	0.533	1	2	0.667	1	3	0.880	1	4	0.685	2	2	40
242	243	0.090	1	1	0.090	1	1	0.263	2	2	0.090	1	1	9
243	244	1.100	1	1	1.100	1	1	1.812	2	2	1.100	1	1	110
244	245	0.352	1	2	0.374	1	1	0.440	1	2	0.374	1	1	33
245	246	0.590	1	1	0.590	1	1	0.833	2	2	0.590	1	1	59
246	247	0.220	1	1	0.293	1	2	0.565	2	3	0.360	2	2	22
247	248	0.610	1	1	0.857	2	2	1.060	2	2	0.857	2	2	61
248	249	0.213	1	2	0.277	1	3	0.331	1	4	0.235	1	3	16
249	250	2.165	2	1	2.290	3	1	2.415	4	1	2.415	4	1	204
250	251	0.780	1	1	1.196	1	2	1.716	1	4	1.061	2	2	78
251	252	0.590	1	1	1.266	2	2	1.856	2	4	0.912	2	3	59
252	253	0.240	1	1	0.413	2	2	0.493	2	2	0.413	2	2	24
253	209	0.070	1	1	0.195	2	1	0.232	2	2	0.195	2	1	7
209	210	1.760	1	1	2.824	2	2	3.997	2	4	2.362	3	2	176
210	211	0.600	1	2	0.965	2	3	1.115	2	4	0.970	3	2	45
211	212	0.168	1	2	0.514	3	3	0.482	3	4	0.506	3	4	12
212	213	1.010	1	1	1.741	2	2	2.414	2	4	1.597	3	3	101
213	214	0.389	3	3	0.588	4	4	0.540	4	4	0.485	3	4	8
214	215	1.125	4	1	1.275	4	2	1.525	4	2	1.325	4	2	75
215	216	0.285	2	2	0.295	2	1	0.500	3	2	0.420	3	1	15
216	217	0.865	2	1	0.865	2	1	1.385	3	2	1.039	3	2	74
217	218	0.295	2	1	0.295	2	1	0.511	3	2	0.420	3	1	17
218	219	0.418	2	2	0.565	2	4	0.807	3	4	0.543	3	2	22
219	220	0.594	2	4	1.038	2	4	1.607	3	4	0.916	3	4	37

220	221	0.576	1	2	0.900	1	2	1.260	1	4	0.720	1	2	54
		15.638			21.473			29.039			20.589			1358
Surrey Kwantlen Path 1														
		A			**P**			**Q**			**S**			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
200	254	0.520	1	1	0.520	1	1	0.693	1	2	0.645	2	1	52
254	255	0.090	1	1	0.090	1	1	0.120	1	2	0.090	1	1	9
255	256	0.290	1	1	0.290	1	1	0.570	2	2	0.309	1	2	29
256	257	0.190	1	1	0.603	4	2	0.416	2	2	0.228	1	2	19
257	258	0.660	1	1	0.704	1	2	1.181	2	2	0.748	1	3	66
258	259	0.120	1	1	0.144	1	2	0.309	2	2	0.269	2	2	12
259	260	0.640	1	1	0.981	1	2	1.533	2	4	0.936	2	2	64
260	261	0.305	2	1	0.341	2	2	0.401	2	2	0.591	4	2	18
261	262	0.715	2	1	1.187	2	3	1.351	3	4	1.155	3	3	59
262	263	0.851	4	2	1.123	4	3	1.304	4	4	1.032	4	4	34
263	264	0.130	1	1	0.324	2	2	0.411	2	4	0.281	2	2	13
264	265	0.380	1	1	0.606	2	2	0.733	2	2	0.632	2	3	38
265	266	0.120	1	1	0.293	2	2	0.397	2	4	0.261	2	3	12
266	267	0.210	1	1	0.461	2	2	0.601	2	3	0.405	2	3	21
267	268	0.645	3	2	0.893	4	2	1.016	4	2	0.893	4	2	37
268	269	0.448	1	2	0.601	2	1	0.825	2	2	0.726	3	1	42
269	270	2.950	3	3	3.939	4	4	3.939	4	4	3.507	4	3	162
270	271	0.855	2	1	1.244	2	2	1.856	3	4	1.300	4	2	73
271	272	0.225	2	1	0.265	2	3	0.443	3	4	0.272	2	3	10
272	273	1.535	2	1	2.099	2	3	2.976	3	4	2.193	2	3	141
273	274	0.345	2	1	0.389	2	2	0.587	3	2	0.389	2	2	22
274	275	1.685	2	1	2.330	3	2	3.370	3	4	1.935	4	1	156
		13.909			19.428			25.034			18.796			1089

Surrey Kwantlen Path 2

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
200	201	1.650	1	1	2.200	1	2	3.630	1	3	1.775	2	1	165
201	202	0.360	2	2	0.374	2	1	0.617	3	2	0.374	2	1	22
202	276	0.685	2	1	0.797	2	2	1.109	3	2	0.959	3	2	56
276	277	0.295	2	1	0.340	2	2	0.522	3	2	0.477	3	3	17
277	278	0.820	1	1	1.289	3	2	1.687	4	2	1.343	3	3	82
278	279	0.280	1	1	0.392	1	2	0.760	2	4	0.442	2	3	28
279	280	1.338	2	2	1.884	2	3	2.188	2	4	1.767	3	3	91
280	281	1.065	2	1	1.316	2	2	1.754	3	2	1.378	2	3	94
281	282	0.370	3	1	0.567	4	2	0.647	4	4	0.535	4	3	12
282	283	2.625	2	3	3.850	3	4	4.150	3	4	3.575	4	3	150
283	284	0.255	2	1	0.380	3	1	0.574	4	2	0.380	3	1	13
284	285	2.058	2	2	3.053	3	3	3.662	4	4	2.667	3	3	145
285	273	0.557	3	2	0.631	2	4	0.958	4	4	0.603	3	2	23
273	274	0.404	2	4	0.668	2	4	1.057	3	4	0.521	2	4	22
274	275	1.789	2	2	2.850	3	2	3.890	3	4	2.455	4	2	156
		14.551			20.591			27.203			19.251			1076

Surrey Kwantlen Path 3

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
200	201	1.650	1	1	2.200	1	2	3.630	1	3	1.775	2	1	165
201	202	0.360	2	2	0.374	2	1	0.617	3	2	0.374	2	1	22
202	276	0.685	2	1	0.797	2	2	1.109	3	2	0.959	3	2	56
276	277	0.295	2	1	0.340	2	2	0.522	3	2	0.477	3	3	17
277	278	0.820	1	1	1.289	3	2	1.687	4	2	1.343	3	3	82
278	279	0.280	1	1	0.392	1	2	0.760	2	4	0.442	2	3	28
279	280	1.338	2	2	2.188	2	3	2.794	2	4	1.767	3	3	91
280	269	0.541	2	2	0.775	2	2	1.160	3	4	0.645	2	2	39
269	270	2.950	3	3	3.939	4	4	3.939	4	4	3.507	4	3	162
270	271	0.855	2	1	1.244	2	2	1.856	3	4	1.300	4	2	73
271	272	0.225	2	1	0.265	2	3	0.443	3	4	0.272	2	3	10
272	273	1.535	2	1	2.099	2	3	2.976	3	4	2.193	2	3	141
273	274	0.345	2	1	0.389	2	2	0.587	3	2	0.389	2	2	22
274	275	1.685	2	1	2.330	3	2	3.370	3	4	1.935	4	1	156
		13.564			18.621			25.450			17.378			1064

Surrey Fitness Path 1

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
286	287	0.540	1	1	0.790	3	1	1.203	4	2	0.790	3	1	54
287	288	0.225	2	1	0.252	2	2	0.410	3	2	0.508	4	3	10
288	289	0.050	1	1	0.185	2	2	0.202	2	2	0.438	4	2	5
289	290	0.850	1	1	1.145	2	2	1.428	2	2	1.327	3	2	85
290	291	0.100	1	1	0.245	2	2	0.278	2	2	0.252	2	2	10
291	292	0.400	1	1	0.738	2	2	1.005	2	3	0.632	2	2	40
292	293	0.475	2	1	0.857	3	3	1.160	3	4	0.740	3	3	35

293	294	1.378	2	2	2.005	2	3	2.945	3	4	1.441	2	2	94
294	295	0.591	3	2	0.802	4	2	0.908	4	2	0.802	4	2	32
295	296	0.782	2	3	1.130	2	4	1.642	3	4	1.062	3	4	58
296	297	0.325	2	1	0.570	3	2	0.828	4	4	0.642	4	3	20
297	298	0.275	2	1	0.480	3	2	0.705	4	4	0.565	4	2	15
298	299	2.184	2	2	3.595	3	2	5.007	4	4	3.334	4	4	193
299	300	0.084	1	4	0.121	1	4	0.168	1	4	0.098	1	4	7
300	301	0.630	3	1	1.084	4	2	1.464	4	4	0.856	4	2	38
301	302	0.505	2	4	0.830	3	4	1.155	4	4	0.855	4	4	30
302	303	0.500	1	1	0.800	1	2	1.258	2	4	0.667	1	3	50
303	304	0.220	1	1	0.264	1	2	0.462	2	2	0.264	1	2	22
304	305	0.820	1	1	1.312	1	2	1.984	2	4	1.093	1	3	82
305	306	0.325	2	1	0.365	2	2	0.557	3	2	0.240	1	2	20
306	200	0.685	2	1	0.797	2	2	1.109	3	2	0.709	1	2	56
		11.945			18.368			25.879			17.315			956

Surrey Fitness Path 2

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
286	287	0.540	1	1	0.790	3	1	1.203	4	2	0.790	3	1	54
287	288	0.225	2	1	0.252	2	2	0.410	3	2	0.508	4	3	10
288	289	0.050	1	1	0.185	2	2	0.202	2	2	0.438	4	2	5
289	290	0.850	1	1	1.145	2	2	1.428	2	2	1.327	3	2	85
290	291	0.100	1	1	0.245	2	2	0.278	2	2	0.252	2	2	10
291	292	0.400	1	1	0.738	2	2	1.005	2	3	0.632	2	2	40
292	293	0.475	2	1	0.857	3	3	1.160	3	4	0.740	3	3	35
293	307	0.705	2	1	0.976	2	3	1.410	3	4	1.053	2	4	58
307	308	1.300	3	1	1.635	4	2	1.985	4	2	1.705	4	2	105
308	296	0.505	4	1	0.548	4	2	0.661	4	4	0.505	4	1	13

296	297	0.325	2	1	0.570	3	2	0.828	4	4	0.642	4	3	20
297	298	0.275	2	1	0.480	3	2	0.705	4	4	0.565	4	2	15
298	299	2.184	2	2	3.595	3	2	5.007	4	4	3.334	4	4	193
299	300	0.084	1	4	0.121	1	4	0.168	1	4	0.098	1	4	7
300	301	0.630	3	1	1.084	4	2	1.464	4	4	0.856	4	2	38
301	302	0.505	2	4	0.830	3	4	1.155	4	4	0.855	4	4	30
302	303	0.500	1	1	0.800	1	2	1.258	2	4	0.667	1	3	50
303	304	0.220	1	1	0.264	1	2	0.462	2	2	0.264	1	2	22
304	305	0.820	1	1	1.312	1	2	1.984	2	4	1.093	1	3	82
305	306	0.325	2	1	0.365	2	2	0.557	3	2	0.240	1	2	20
306	200	0.685	2	1	0.797	2	2	1.109	3	2	0.709	1	2	56
		11.703			17.590			24.440			17.273			948

Surrey Fitness Path 3

		A			P			Q			S			d
From	To	β	α	β	α			β	α		β	α		
286	309	0.299	1	2	0.567	3	1	0.786	4	2	0.567	3	1	28
309	310	0.625	2	1	1.025	2	3	1.183	3	4	1.017	3	3	50
310	311	0.440	3	1	0.578	4	2	0.616	4	2	0.590	4	3	19
311	312	0.345	2	1	0.477	2	2	0.749	3	3	0.558	3	4	22
312	313	0.214	2	4	0.395	3	4	0.455	3	4	0.371	3	4	7
313	314	0.405	2	1	0.605	3	2	0.698	3	2	0.623	3	3	28
314	315	0.225	2	1	0.377	3	2	0.410	3	2	0.383	3	3	10
315	316	0.515	2	1	0.744	3	2	0.874	3	2	0.770	3	3	39
316	317	0.218	2	2	0.385	3	3	0.409	3	4	0.367	3	3	7
317	318	0.285	2	1	0.453	3	2	0.506	3	2	0.463	3	3	16
318	319	0.605	4	1	0.666	4	2	0.743	4	2	0.682	4	3	23
319	320	0.132	1	3	0.329	2	4	0.377	2	4	0.549	4	4	9
320	321	0.900	1	1	1.265	2	2	1.565	2	2	1.575	4	3	90

321	322	0.578	2	2	0.692	2	3	0.998	3	4	0.453	1	2	34
322	323	0.090	1	1	0.233	2	2	0.263	2	2	0.364	3	2	9
323	324	0.253	1	2	0.492	2	3	0.556	2	4	0.567	3	3	19
324	325	0.110	1	1	0.301	2	2	0.374	2	4	0.397	3	3	11
325	326	0.584	2	2	0.823	3	3	0.967	3	3	0.977	4	4	43
326	327	0.090	1	1	0.239	2	2	0.269	2	2	0.495	4	3	9
327	328	0.070	1	1	0.214	2	2	0.237	2	2	0.468	4	3	7
328	329	0.445	2	1	0.530	2	2	0.762	3	2	0.552	2	3	32
329	330	0.627	1	2	1.034	2	3	1.190	2	4	0.908	2	3	47
330	331	0.235	2	1	0.286	2	3	0.382	3	2	0.426	3	4	11
331	332	0.658	2	2	0.898	2	3	1.157	3	4	0.792	2	3	40
332	302	0.275	2	1	0.415	2	2	0.690	3	4	0.325	2	3	15
302	303	0.533	1	2	0.700	1	2	0.992	2	2	0.733	1	3	50
303	304	0.220	1	1	0.279	1	2	0.477	2	2	0.293	1	3	22
304	305	0.820	1	1	1.312	1	2	1.984	2	4	1.148	1	4	82
305	306	0.325	2	1	0.378	2	2	0.570	3	2	0.267	1	3	20
306	200	0.685	2	1	0.834	2	2	1.146	3	2	0.747	1	3	56
		11.806			17.526			22.383			18.428			855

Richmond City Hall Path 1

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
400	401	0.090	1	1	0.108	1	2	0.138	1	2	0.239	2	2	9
401	402	0.224	1	2	0.280	1	2	0.280	1	2	0.294	1	2	21
402	403	0.381	2	2	0.445	2	2	0.570	3	2	0.586	3	2	24
403	404	0.245	2	1	0.269	2	2	0.434	3	2	0.277	2	2	12
404	405	1.140	1	1	1.873	2	2	2.633	2	4	1.569	2	2	114
405	406	0.335	2	1	0.335	2	1	0.530	3	2	0.224	1	2	21
406	407	1.909	1	2	2.631	2	2	3.228	2	2	2.750	2	3	179
407	408	0.240	1	1	0.413	2	2	0.493	2	2	0.538	3	2	24
408	409	0.907	1	2	1.542	2	2	2.108	2	4	1.315	2	2	85
409	410	0.110	1	1	0.257	2	2	0.257	2	2	0.264	2	2	11
410	411	0.530	1	1	0.761	2	2	0.938	2	2	0.761	2	2	53
411	412	0.170	1	1	0.181	1	2	0.181	1	2	0.204	1	4	17
412	413	0.485	2	1	0.610	3	1	0.735	4	1	0.634	3	2	36
		6.766			9.705			12.525			9.656			606

Richmond City Hall Path 2

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
400	401	0.090	1	1	0.108	1	2	0.138	1	2	0.239	2	2	9
401	414	0.594	2	2	0.712	2	3	0.837	3	3	0.866	3	4	44
414	415	0.075	1	2	0.348	3	2	0.371	3	2	0.478	4	2	7
415	416	0.415	2	1	0.695	3	2	0.888	3	4	0.617	3	2	29
416	417	0.338	2	2	0.432	2	3	0.663	3	4	0.445	2	3	20
417	418	0.705	2	1	0.937	2	3	1.178	3	4	0.976	2	3	58
418	419	0.335	2	1	0.405	2	2	0.712	3	4	0.474	3	2	21

419	420	0.455	2	1	0.521	2	2	0.756	3	2	0.668	3	2	33
420	422	0.140	1	1	0.321	2	3	0.396	2	4	0.455	3	3	14
422	423	0.265	2	1	0.293	2	2	0.465	3	2	0.427	3	2	14
423	424	0.255	2	1	0.324	2	2	0.536	3	4	0.415	3	2	13
424	425	0.400	1	1	0.605	2	2	0.738	2	2	0.757	3	2	40
425	426	0.160	1	1	0.317	2	2	0.317	2	2	0.453	3	2	16
426	427	0.655	2	1	0.761	2	2	0.886	3	2	0.921	3	2	53
427	428	0.335	2	1	0.447	2	2	0.712	3	4	0.391	2	2	21
428	429	0.185	2	1	0.197	2	2	0.342	3	2	0.201	2	2	6
429	430	0.221	2	2	0.251	2	2	0.406	3	2	0.382	3	3	9
430	431	1.234	2	2	1.512	2	2	1.637	3	2	1.831	4	2	104
431	432	0.335	2	1	0.335	2	1	0.530	3	2	0.474	3	2	21
432	411	0.320	1	1	0.509	2	2	0.616	2	2	0.530	2	2	32
411	412	0.170	1	1	0.204	1	2	0.204	1	2	0.215	1	2	17
412	413	0.485	2	1	0.682	3	2	0.807	4	2	0.706	3	2	36
		8.168			10.915			14.134			12.921			617
Richmond City Hall Path 3														
		A			**P**			**Q**			**S**			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
400	401	0.090	1	1	0.108	1	2	0.108	1	2	0.239	2	2	9
401	402	0.210	1	1	0.252	1	2	0.322	1	2	0.266	1	2	21
402	433	0.325	2	1	0.365	2	2	0.557	3	2	0.503	3	2	20
433	434	4.780	1	1	5.736	1	2	5.861	2	2	5.861	2	2	478
434	435	0.120	1	2	0.293	2	3	0.323	2	4	0.388	3	2	9
435	436	1.053	2	2	1.633	2	2	2.338	3	4	1.343	2	2	87
436	437	0.565	2	2	0.888	3	3	1.123	4	4	0.697	2	4	33
437	438	0.930	1	1	1.116	1	2	1.551	2	2	1.116	1	2	93
438	413	0.420	1	1	0.420	1	1	0.545	2	1	0.545	2	1	42

		8.493			10.811			12.728			10.958			792
Richmond Hospital Path 1														
		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
400	401	0.090	1	1	0.108	1	2	0.138	1	2	0.239	2	2	9
401	439	1.010	2	2	1.508	2	2	2.187	3	3	1.412	3	2	83
439	440	0.200	1	1	0.325	2	1	0.392	2	2	0.463	3	2	20
440	441	1.340	1	1	1.465	2	1	2.180	2	2	1.679	3	2	134
441	442	0.280	1	1	0.448	1	2	0.760	2	4	0.498	2	3	28
442	443	0.917	1	2	1.491	1	2	2.189	2	4	1.386	2	3	86
443	444	0.265	2	1	0.446	3	3	0.646	4	4	0.455	3	3	14
444	445	1.880	1	2	2.569	2	3	3.321	2	4	2.318	3	3	141
445	446	0.435	2	1	0.497	2	2	0.725	3	2	0.518	2	2	31
446	447	1.640	1	1	2.202	2	2	2.749	2	2	2.312	2	3	164
447	448	0.140	1	1	0.349	2	2	0.442	2	4	0.437	3	3	14
448	449	0.615	2	1	0.713	2	2	0.838	3	2	0.871	3	2	49
449	450	0.215	2	1	0.233	2	2	0.388	3	2	0.489	4	2	9
450	451	0.775	2	1	0.905	2	2	1.122	2	2	1.073	3	2	65
451	452	0.245	2	1	0.269	2	2	0.434	3	2	0.402	3	2	12
452	453	1.100	1	1	1.518	2	2	1.885	2	2	1.592	2	3	110
453	454	0.180	1	1	0.240	1	2	0.521	2	4	0.180	1	1	18
454	455	0.525	2	1	0.757	3	2	0.882	4	2	0.685	2	4	40
455	456	0.740	1	1	0.888	1	2	0.888	1	2	1.013	2	2	74
		12.593			16.931			22.685			18.022			1101

Richmond Hospital Path 2														
		A			**P**			**Q**			**S**			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
400	401	1.650	1	1	2.200	1	1	3.630	1	2	1.775	2	2	9
401	402	0.360	2	1	0.374	2	2	0.617	3	2	0.374	2	2	21
402	433	0.685	2	1	0.797	2	2	1.109	3	4	0.959	3	3	20
433	457	0.685	2	1	0.797	2	2	1.109	3	2	0.959	3	2	251
457	458	0.685	2	1	0.797	2	1	1.109	3	2	0.959	3	2	15
458	459	0.685	2	1	0.797	2	2	1.109	3	4	0.959	3	3	13
459	460	0.685	2	1	0.797	2	2	1.109	3	2	0.959	3	2	28
460	461	0.685	2	1	0.797	2	2	1.109	3	2	0.959	3	2	30
461	462	0.685	2	1	0.797	2	2	1.109	3	2	0.959	3	2	14
462	463	0.685	2	1	0.797	2	1	1.109	3	2	0.959	3	2	87
463	464	0.685	2	1	0.797	2	3	1.109	3	4	0.959	3	3	15
464	446	0.685	2	1	0.797	2	2	1.109	3	2	0.959	3	2	35
446	447	0.685	2	1	0.797	2	1	1.109	3	2	0.959	3	2	164
447	448	0.685	2	1	0.797	2	2	1.109	3	4	0.959	3	2	14
448	449	0.280	1	1	0.392	1	2	0.760	2	2	0.442	2	2	49
449	450	1.338	2	1	1.884	2	2	2.188	2	2	1.767	3	2	9
450	451	1.065	2	1	1.316	2	2	1.754	3	2	1.378	2	3	65
451	452	0.370	3	1	0.567	4	2	0.647	4	2	0.535	4	3	12
452	453	2.625	2	1	3.850	3	1	4.150	3	2	3.575	4	2	110
453	454	0.255	2	1	0.380	3	2	0.574	4	4	0.380	3	2	18
454	455	2.058	2	1	3.053	3	1	3.662	4	2	2.667	3	2	40
455	456	0.557	3	1	0.631	2	1	0.958	4	2	0.603	3	2	74
		18.778			24.212			32.243			25.008			1093

Richmond Hospital Path 3

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
400	401	0.090	1	1	0.114	1	2	0.114	1	2	0.245	2	3	9
401	402	0.224	1	2	0.280	1	2	0.350	1	2	0.294	1	2	21
402	433	0.325	2	1	0.432	2	2	0.690	3	4	0.503	3	2	20
433	465	2.740	1	1	2.740	1	1	3.413	2	2	3.048	2	2	274
465	466	0.090	1	1	0.144	1	2	0.204	1	4	0.245	2	3	9
466	467	0.335	2	1	0.377	2	2	0.572	3	2	0.516	3	2	21
467	468	0.150	1	1	0.305	2	2	0.305	2	2	0.440	3	2	15
468	469	0.285	2	1	0.410	3	1	0.620	4	2	0.546	4	2	16
469	470	0.260	1	1	0.454	2	2	0.541	2	2	0.722	4	3	26
470	471	0.392	2	2	0.575	2	2	0.867	3	3	0.633	3	3	25
471	472	0.625	2	1	0.825	2	3	1.217	3	4	0.983	3	3	50
472	473	1.630	1	1	3.586	1	3	5.216	1	4	2.608	1	2	163
473	474	1.440	1	1	2.813	2	3	3.773	2	4	2.554	3	2	144
474	475	0.533	1	2	1.263	3	4	1.655	4	4	0.890	3	2	40
475	476	2.072	2	2	3.949	3	3	5.047	4	4	2.948	2	2	146
476	477	0.274	2	2	0.465	3	3	0.664	4	4	0.349	2	4	14
477	456	1.385	2	1	1.637	2	2	1.762	3	2	1.596	1	2	126
		12.850			20.369			27.010			19.120			1119

Richmond Market Path 1

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
400	401	0.090	1	1	0.108	1	2	0.108	1	2	0.239	2	2	9
401	439	0.885	1	2	1.162	1	2	1.439	1	2	1.217	1	3	83
439	478	0.840	1	1	0.965	2	1	1.413	2	2	1.146	3	2	84
478	479	0.242	2	2	0.286	2	2	0.360	2	4	0.375	3	1	11

479	480	1.005	2	1	1.181	2	2	1.474	2	2	1.365	3	2	88
480	481	0.210	1	1	0.335	2	1	0.447	2	2	0.349	2	2	21
481	482	0.180	1	1	0.341	2	2	0.401	2	2	0.478	3	2	18
482	483	0.460	1	1	0.830	2	2	1.137	2	4	0.833	3	2	46
483	484	0.310	1	1	0.497	2	2	0.600	2	2	0.518	2	2	31
484	485	0.970	1	1	1.289	2	2	1.289	2	2	1.479	3	2	97
		5.193			6.995			8.668			7.998			488

Richmond Market Path 2

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
400	401	0.090	1	1	0.090	1	1	0.108	1	2	0.221	2	2	9
401	439	0.830	1	1	0.996	1	2	1.273	1	2	1.051	1	2	83
439	440	0.210	1	1	0.377	2	2	0.447	2	2	0.516	3	2	21
440	441	1.340	1	1	1.733	2	2	2.180	2	2	1.947	3	2	134
441	486	1.880	1	1	2.256	1	2	3.008	2	2	2.506	2	2	188
486	487	0.180	1	1	0.377	2	3	0.473	2	4	0.389	2	3	18
487	485	0.050	1	1	0.185	2	2	0.202	2	2	0.310	3	2	5
		4.580			6.014			7.690			6.941			458

Richmond Market Path Path 3

		A			P			Q			S			
From	To	β	a_N	a_P	β	a_N	a_P	β	a_P	a_P	β	a_N	a_P	d
400	401	0.090	1	1	0.090	1	1	0.090	1	1	0.221	2	2	9
401	488	0.420	1	1	0.644	1	2	0.924	1	3	0.532	1	2	42
488	489	2.312	2	2	2.573	3	1	2.573	3	1	2.835	4	2	205
489	480	1.110	1	1	1.235	2	1	1.952	3	2	1.309	2	2	111
480	490	0.230	1	1	0.401	2	2	0.478	2	2	0.416	2	2	23
490	482	0.355	2	1	0.605	4	1	0.728	4	2	0.620	4	2	23

482	483	0.460	1	1	0.861	2	2	1.168	2	4	0.863	3	3	46
483	484	0.310	1	1	0.497	2	2	0.497	2	2	0.497	2	2	31
484	485	1.035	1	2	1.224	2	3	1.224	2	3	1.414	3	4	97
		6.321			8.131			9.634			8.708			587